POWER

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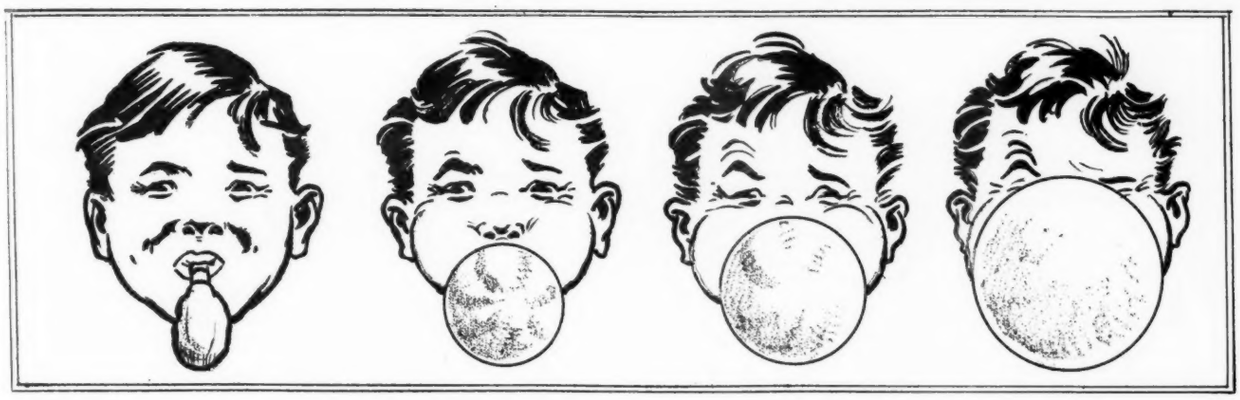


Rubber Balloons and Reputations

By RUFUS T. STROHM

YOU'VE seen these toy balloons that hawkers sell to children at the County Fair and to grown-ups during Old Home Week. At first sight there's nothing to them. They look like a bunch of dejected frankfurters.

You take one of them and you begin to blow into it. First off, it straightens out like a sore finger. Then it begins to grow and before long it looks like a watermelon with the jaundice. You keep on blowing, watching it swell, till it gets so thin you can almost see through it.

At that stage you have a feeling that maybe you had better stop, but you overrule your timidity and decide to give it one more lungful. Then the blamed thing goes "plop!" leaving you with a hunk of rubber and a foolish expression.

The trouble is you've forgotten about the factor of safety.

That's what many a man does when he starts to advertise himself.

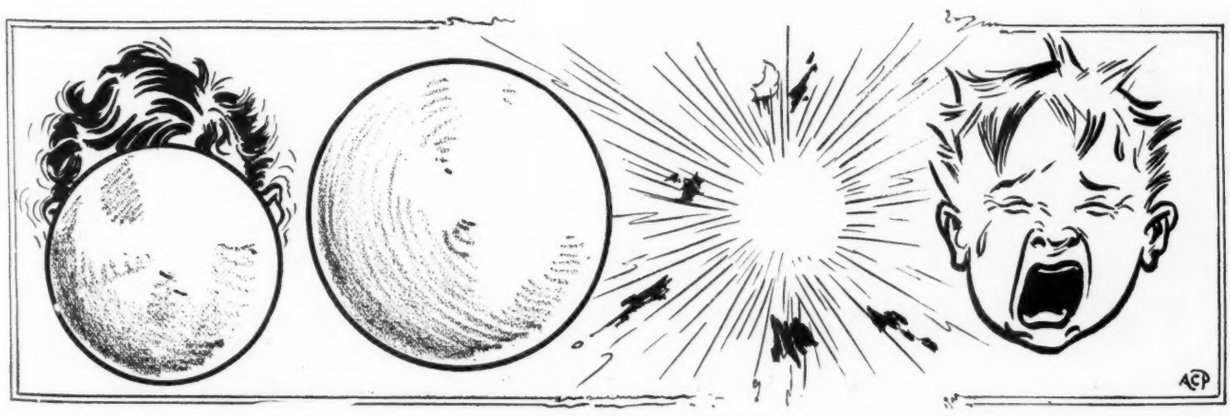
At first he's sort of fearful about it. He gives his reputation a gentle little puff and is tickled pink to see how it perks up. Instead of a limp and sickish-looking thing, it stands out so that folks take notice of it.

He draws a long breath, blows once more and notes greater rotundity and increased prominence. He blows again and again and marvels at the result. Apparently there is no limit to the expansion.

The thing grows till he loses all sense of its size. It is so close to him that it obscures his vision and he sees only its sweeping curves. But it seems to show no signs of strain, so he gives himself up to a riot of blowing.

Then, without warning, it goes "bang!" and he finds himself alone with a vain regret and the echo of unsympathetic laughter.

You can stretch almost any old reputation if you patch up the weak spots and vulcanize the seams. But you've got to use judgment as to when to stop.

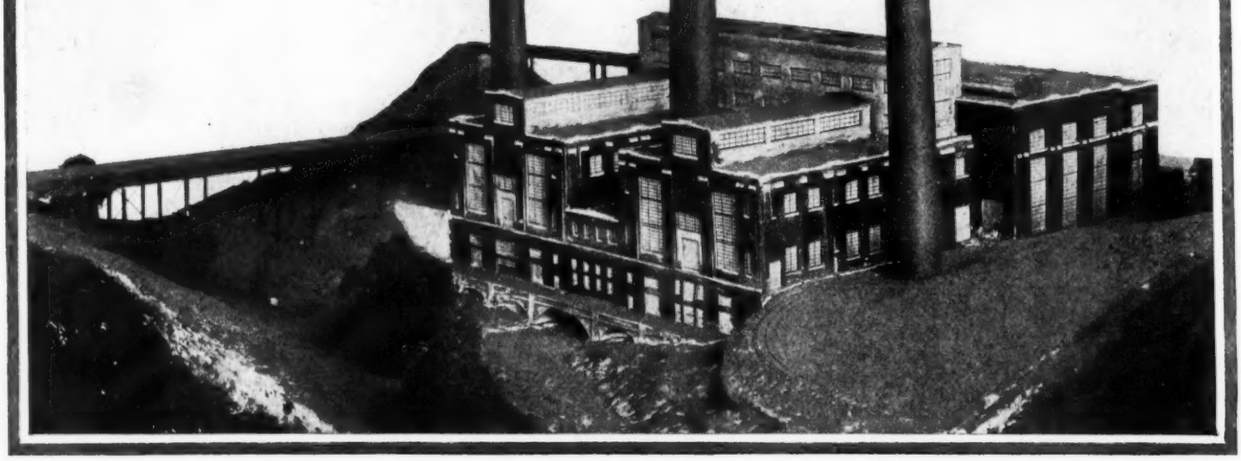


United States Nitrate Plant, No. 2

at Muscle Shoals, Ala.

THE BOILER ROOM

By Charles H. Bromley



The first of several articles describing fully the large steam-power station of United States Nitrate Plant No. 2, at Muscle Shoals, Ala., where great quantities of ammonium nitrate were to have been made by the cyanamid processes for the Ordnance Department of the Army. Data are given on the flow and available power of the Tennessee River at Muscle Shoals, Ala. The conditions upon which to base the design of this interesting war steam station of 90,000 kw. are the most ideal engineers have yet encountered. The combustion volume in the boiler furnaces is 11.6 cu.ft. per sq.ft. of active stoker-grate area; the settings are of the most modern type. A total steam temperature of 590 deg. F. will be used, though a somewhat higher temperature may be used later. The plant-load factor will be about 95 per cent., the load being chiefly electric furnaces. Accompanying the article is a table giving many important data covering the entire station, data which the designing, consulting and operating engineer would like to file. A plant thermal efficiency of 20 per cent. is expected.

LET us first get a perspective view of Muscle Shoals that we may the better assess what will follow.

The steam station is on the Tennessee River at Muscle Shoals, about three miles from Sheffield and about the same distance from Florence. As is well known, the Tennessee River is pregnant with great power possibilities, and cheap power, when coal, iron and many raw materials are near at hand, as they are in that part of the South, coupled with the fact that it is only about 300 miles to seaports on the Gulf of Mexico and a little more to others on the Atlantic Seaboard, will likely lead to the development of this section of the country.

Many power studies of the Tennessee River have been made, particularly during the last 32 years. The chart, Fig. 1, shows the energy available at Muscle Shoals; study of it is worth while; but only a few figures will be given here to acquaint the reader with the river. The maximum flow at Florence, Ala., was 499,000 c.f.s. for two hours on Mar. 19, 1897, gage height 32.5 ft. The minimum flow recorded at the same place was 7000 c.f.s., gage height —0.8 ft., October, 1872 and September, 1878. The flow has never been up to 240,000 c.f.s. from April to October, and 150,000 c.f.s. averages only once every two years. The average flows for a period of 32 years are given below.

AVERAGE FLOWS OF TENNESSEE RIVER AT FLORENCE FOR 32 YEARS

Number of Days per Year Flow Was Above Cubic-Foot-Seconds						
50,000	100,000	150,000	200,000	250,000	300,000	400,000
Gage Height, Ft.						
5.2	9.7	13.4	16.6	19.6	22.4	27.6
122.9	47.9	23.4	11.8	5.6	2.4	0.35

The commercial power available from the river at Muscle Shoals, connected with other plants, is estimated by army engineers at 600,000 hp.

The total cost of the project now under way for

water-power development at Muscle Shoals was estimated in October, 1917, to be $14,534,000, based upon then prevailing wages and prices of materials. On Feb. 23, 1918, because of the low price of cement for the Government, the estimate was reduced to $14,000,000. This estimate includes the dam locks and flowage rights and the power house with hydro-electric machinery capable of generating about 120,000 hp. The power-house substructure will be constructed so as to provide for placing additional units in the future if desired, in order to utilize the noncontinuous or secondary power in connection with steam-generating units already installed in Nitrate Plant No. 2. It is estimated that about three years will be required for the completion of the project. Of the power to be furnished by the project, it is estimated that approximately 72,000 hp. will be continuous throughout the year. In all but the dry-up year it is to be expected that approximately 100,000 hp. can be developed continuously. The figures in this paragraph are by Benedict Crowell, Assistant Secretary of War.

There have been many proposals for hydro-electric development at Muscle Shoals. One study proposes ten 18,000-hp. turbines for No. 3 dam and twelve 48,000-hp. units for No. 2 dam. The dam sites have been selected, but the plants have never been built. Transmission lines now connect the Muscle Shoals district with the Warrior River steam station 90 miles away on the Warrior River, and with "Lock No. 12," a hydro-electric station on the Coosa River 160 miles away; both are properties of the Alabama Power Co. Such, broadly, are the geographical and economic circumstances surrounding the large steam station of United States Nitrate Plant, No. 2, though the plant was built to furnish power only to the nitrates plant. The data on river flow are from Document 1262, Sixty-Fourth Congress, First Session, Committee on Rivers and Harbors.

As stated, the new steam plant at Muscle Shoals was built to furnish current for the manufacture of ammonium nitrate by the cyanamid processes for the Government, the Air Nitrates Corporation acting as agent for the Ordnance Department of the United States Army. The station was designed for 90,000 kw. in two main units, one 60,000 kw. normal rating, three-cylinder reaction turbine, and one 30,000-kw. tandem-compound double-flow reaction turbine. In the middle of February, 1918, the ground where the station now stands was a ravine, virtually a virgin forest. Steam has been on the plant four months, and the large main unit is about ready to run. Here, indeed, is an achievement in power-plant design, construction and installation, considering labor, traffic and other conditions. The 30,000-kw. unit will not be installed for the present.

The plant was designed to meet conditions which are by far the nearest approach to the ideal that engineers have ever encountered, so far as the writer and those consulted by him know. It is indeed important that the reader have in mind these conditions when reading the articles. for if he does not have them in mind, but has instead the usual conditions of load factor, etc., he may misjudge.

The station load factor will be 95 per cent. The load is chiefly electric furnaces, of which 12 are called for,

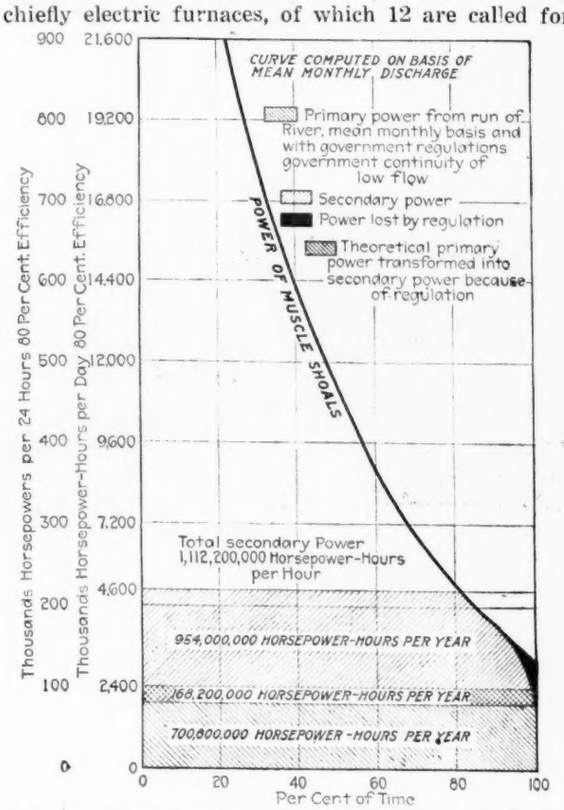

CURVE COMPUTED ON BASIS OF MEAN MONTHLY DISCHARGE
Primary power from run of River, mean monthly basis and with government regulations government continuity of low flow
Secondary power
Power lost by regulation
Theoretical primary power transformed into secondary power because of regulation
POWER OF MUSCLE SHOALS
Total secondary Power 1,112,200,000 Horsepower-Hours per Hour
954,000,000 HORSEPOWER-HOURS PER YEAR
168,200,000 HORSEPOWER-HOURS PER YEAR
700,800,000 HORSEPOWER-HOURS PER YEAR
Thousands Horsepowers per 24 Hours 60 Per Cent. Efficiency
Thousands Horsepower-Hours per Day 60 Per Cent. Efficiency
Per Cent of Time
900 600 700 600 500 400 300 200 100 0
21,600 19,200 16,800 14,400 12,000 9,600 7,200 4,800 2,400 0
0 20 40 60 80 100

FIG. 1. CHART SHOWING WATER POWER AVAILABLE FROM THE TENNESSEE RIVER AT MUSCLE SHOALS

10 to operate continuously, 2 as spares. There are many load curves of these furnaces, and each takes 6000 kw., the plotted line on the recording meter being as uniform as one could carefully draw the line free-hand. The power factor of the furnaces is 86 per cent. at 160-volt operation. The 60,000-kw. three-cylinder main turbine is designed for 85 per cent. power factor; but with the machine up to 90 per cent. power factor a

FIG. 2. THE TENNESSEE RIVER AT MUSCLE SHOALS

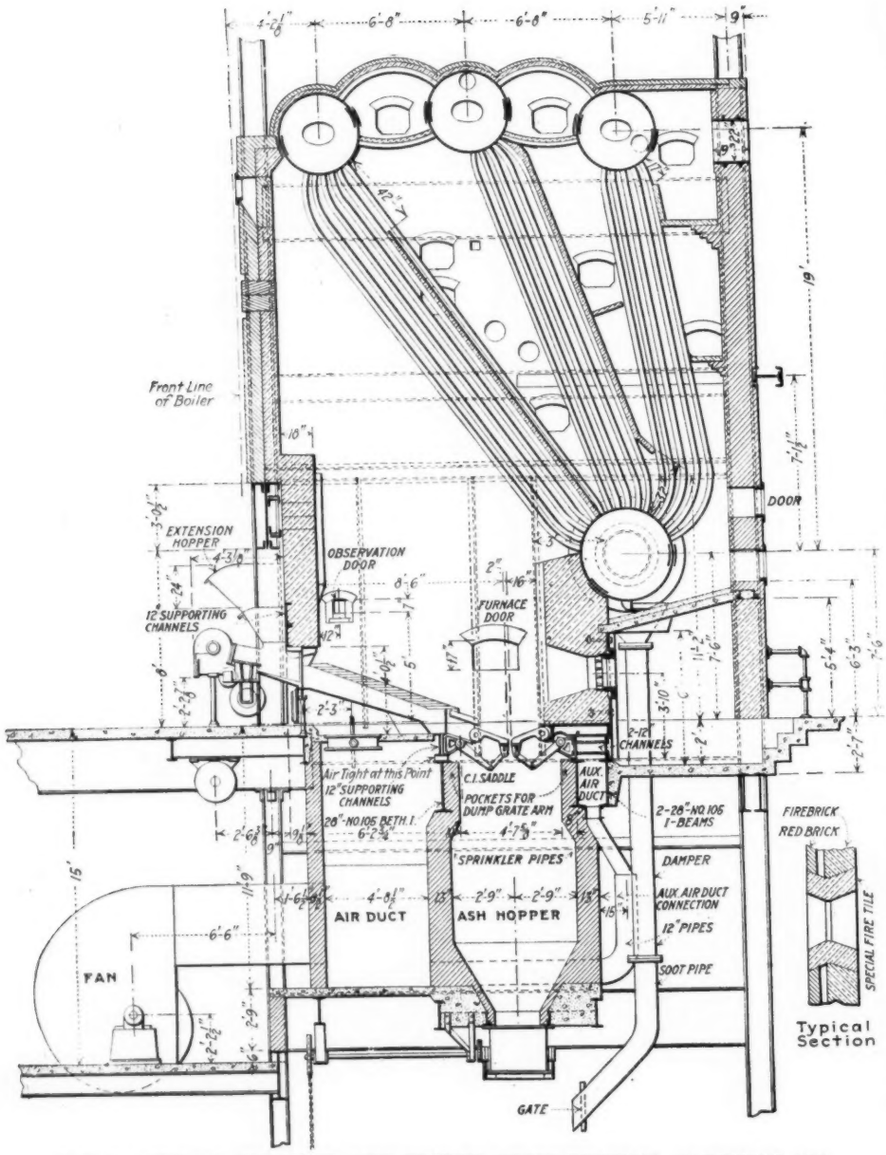


FIG. 3. BOILER, FURNACE AND STOKER CROSS-SECTION, CARRYING ALL IMPORTANT DIMENSIONS

load of 70,000 kw. can be carried without trouble. The water-rate guarantees on the turbine are very low. These, with all other important data, capacities, ratios, etc., the writer has prepared in tabular form convenient for the engineers' notebook, and appear in this article.

An unusually low unit coal consumption is expected; some of those directly interested expect it to be near 1 lb. per kilowatt-hour.

Coal of remarkable composition is available, the analysis being as follows: Fixed carbon, 59 to 60 per cent.; volatile, 35.7 per cent.; sulphur, 0.8 per cent.; moisture, 1.5 per cent.; ash, 4 per cent. The boiler radiation will likely be down to 2½ per cent. because of the use of heat-insulating brick, and the stokers and volume of furnace are such that a boiler efficiency of 76 to 78 per cent. may confidently be expected. The feed water will be kept at 220 deg. F. constantly. All drives throughout the station, except feed pumps and two spare steam-driven exciters, are motor-driven. A large pumping plant for service process water is located in the power plant instead of in a separate station, and these pumps are each driven by a 700-hp. induction motor from current generated by two house turbines each of 2000 kw. capacity, noncondensing, which also supply current for all auxiliaries.

A plant thermal efficiency of at least 20 per cent. is expected, and there are many reasons to believe it will be above this figure. A kilowatt will be put on the board for between 17,000 and 18,000 B.t.u. or better. If one has in mind the unusually favorable conditions for which the plant was designed, one will agree that the performances expected are certain of realization, and that the designing engineers are not overoptimistic.

The Boiler Room

The boiler room and its equipment are admirable in design, arrangement and operation. There are 12 type M-55 Stirling boilers each having 15,070 sq.ft. of heating surface with 15-retort Westinghouse underfeed stokers set as shown in sectional side elevation, Fig. 3. The lower drum is set 7 ft. 6 in. from the normal boiler-room floor, giving a furnace volume of 11.6 cu.ft. per sq.ft. of active grate area, adequate to permit of unusually thorough mixture of air and gases at ratings up to 300 per cent., which is far above the 150 per cent. rating normally required. This is particularly true for the excellent coal with which the plant will be supplied. A view of the boiler furnaces during construction is

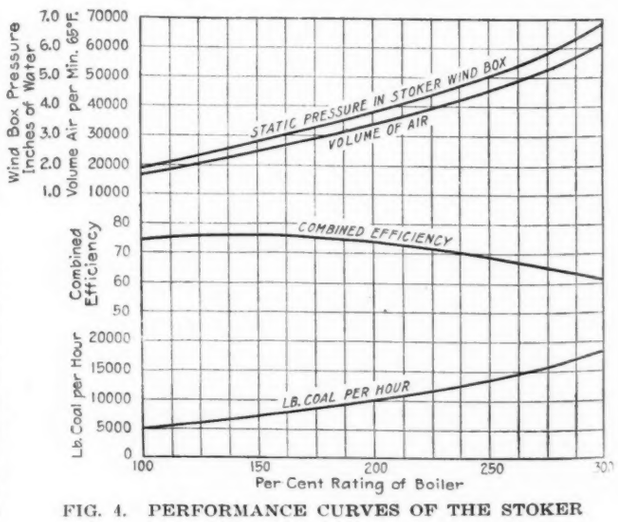

Wind Box Pressure Inches of Water
Volume Air per Min. 65°F.
STATIC PRESSURE IN STOKER WIND BOX
VOLUME OF AIR
Combined Efficiency
COMBINED EFFICIENCY
Lb. Coal per Hour
LB. COAL PER HOUR
Per Cent Rating of Boiler

FIG. 4. PERFORMANCE CURVES OF THE STOKER

shown in Fig. 6. The ash hoppers under the furnaces are unusually large, having capacity of 225 cu.ft. each. Each of the ash cars used for hauling ashes away from the boiler room has a capacity of 1½ cu.yd. The front boiler wall is supported independently of the stoker, and the front furnace wall is so arranged that it is independent of the front boiler wall (see Fig. 3). Four fire-doors are placed in the bridge-wall, the distance center to center of doors being 8 ft.; a section of one of these doorways is shown in Fig. 3. The bridge-wall is 3 ft. thick, but its front is concaved 4½ in. at the center. It extends into the side-walls 3½ in. with 1 in. clearance for expansion. Special fire tile is used around each fire-door. All firebrick lining 9 in. and over is laid with four header courses to the fire, between single stretcher courses. Red brick only is used in the front and side walls below the stokers. The top joint between the top of the furnace-front wall and the front boiler wall is filled with asbestos; both these walls are 18 in. thick including the Silocel brick. The side walls are 2 ft. 3⅜ in. thick at the bottom, with 17½-in. firebrick lining, in four courses of 4½-in. brick around the dump plate; 13½-in. firebrick lining of three courses of 4½-in. brick from here up to within a couple of feet of the gas opening in the first pass; from this point to the top, in the first and second passes, 9-in. firebrick lining in two courses of 4½-in. brick, is used, while for the last pass the firebrick lining is but 4½ in. thick. The rear wall is 18 in. thick, of red brick and Silocel only.

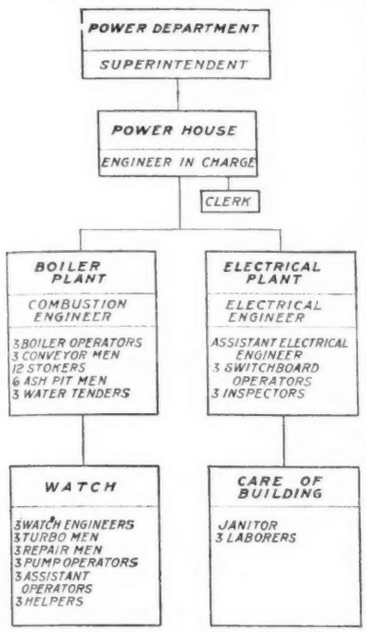


FIG. 5. ORGANIZATION OF PERSONNEL OF MUSCLE SHOALS POWER PLANT

The gas opening in the first pass is 42 in. wide, in the second pass 32 in. wide and in the last pass 17 in. wide. The free area for the passage of gases is: First pass, 40 sq.ft.; second pass, 30.6 sq.ft.; third pass, 16.3 sq.ft. The damper opening is 22 in. wide. All joints in the tile baffles are made on the tubes, the tile being broken where necessary in order to bring the joint on the tube.

The stoker width is 26 ft. 5½ in. The lineshafting is supported from the stoker ram boxes, and each stoker is operated by an independent adjustable-speed motor, 230-volt direct-current field control, 8 hp. at 200 r.p.m. and 13.5 hp. at 1500 r.p.m. Clutches are provided so that any of five groups of three rams each may be stopped temporarily to adjust the fuel bed.

Clinker grinders—that is, rotary ash-discharge apparatus—have not been installed, as the coal eventually to be used has less than 5 per cent. ash of an unusually high fusion temperature.

The curve, Fig. 4, gives the stoker performance based on coal of fixed carbon 56.74 per cent., volatile 29 per cent., moisture 4.23, ash 11.13 per cent., sulphur 2.58 per cent., B.t.u. per lb. 13,000—a very poor coal compared with that with which the plant normally will be supplied. At 150 per cent. rating the guaranteed combined efficiency is 76 per cent., at 175 per cent. rating, 75 per cent. The continuous capacity is 235 per cent.; 275 per cent. for 4 hours. There are three radial-brick chimneys, each 275 ft. high above the boiler-room floor. The internal diameter of the middle chimney is 18 ft.; that of the other two, 14 feet.

The railroad runs to the plant and above the four coal crushers of 100 tons capacity per hour, the coal being dumped directly into the crushers from the cars which in turn bring it from the mine. From the crushers it is conveyed to four 24-in. belt conveyors, each of 100 tons per hour capacity, driven by 15-hp. motors which deliver it to the bunkers. The latter are of steel-frame concrete-lined construction with capacity for 4½ days' normal operation. The yard-storage capacity is 25,000 tons. There are four one-ton larries to each firing aisle which, by the way, is 25 ft. wide.

Each boiler has its individual forced-draft radial-flow double-inlet fan. Each fan has two 60-cycle three-phase squirrel-cage induction motors, one 40 hp. for a speed of 875 r.p.m., and one 75 hp. for 1170 r.p.m. Against 3-in. static pressure these fans will deliver 25,500 cu.ft. per min. (745 r.p.m.); against 5.1 in. pressure, 40,500 cu.ft. per min. (895 r.p.m.); against 6 in., 48,000 cu.ft. per min. (1200 r.p.m.).

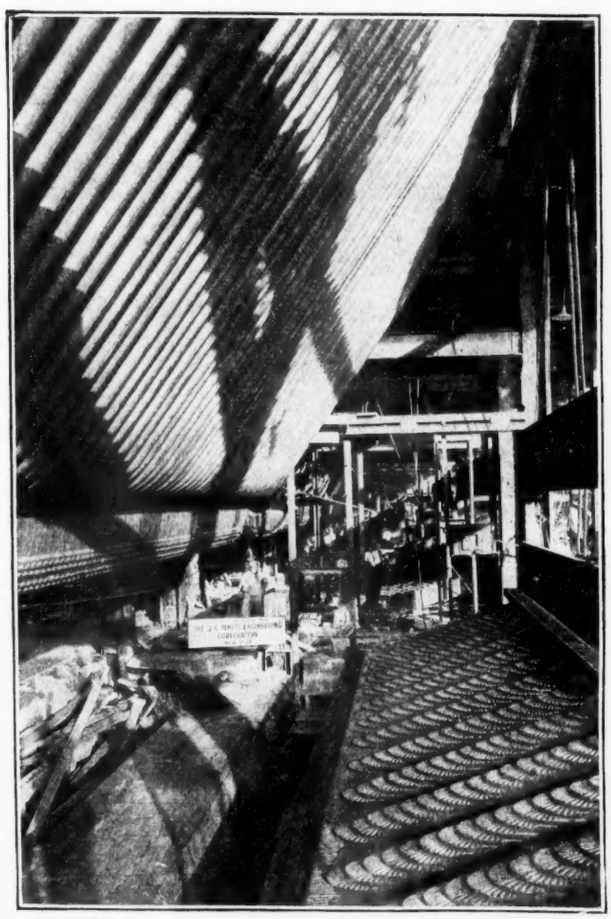


FIG. 6. VIEW OF BOILER FURNACE, INTERIOR, DURING CONSTRUCTION: NOTE LARGE COMBUSTION VOLUME

This arrangement of fans, it is realized, is rather unusual, not so much because one fan is furnished each boiler, but because each fan has two motors to drive it. The control of the draft is as automatic as reliable apparatus can make it consistent with efficient operation, and these fans will cut in and out automatically. The intakes to them are short and the air will be quite clean despite the lime and carbide dust from the cyanamid plant.

The treatment is as follows: Pounds of soda per 1000 gal., 0.27; pounds of lime (50 per cent.) per 1000 gal., 0.55. Two 15,000-hp. feed-water heaters are used, each with water capacity of 481 cu.ft., weighing when full of water, 66,337 lb.; empty, each weighs 3C,000 lb. The boiler-feed pumps are all centrifugal, 5-in. four-stage, 750 gal. per min., each driven by a three-stage 2650-r.p.m. steam turbine.

Consideration was given economizers, but they were not installed as they did not show a commercial economy with coal of the price and quality it is possible to obtain. Provision is made for their installation should conditions change and their use be warranted after the plant has been operated for some time.

The boilers are built for 300 lb. pressure and hy-

Important Data on Power Plant of United States Nitrate Plant No. 2 Muscle Shoals, Alabama

GENERAL

Location, Muscle Shoals, Ala., on the Tennessee River near Sheffield and Florence
Main generating capacity, kw. (in one unit) 60,000
Service generating capacity, kw. (non-condensing) 4,000
Auxiliary and other drives ..... Practically all motor
Station load factor, per cent ..... 90 to 95
Nature of load ..... Chiefly electric furnaces
Ammonium nitrate manufactured by the cyanamid processes

BOILER ROOM

Dimension, boiler house ..... overall, length 280 ft., 9 in.; width 158 ft. 9 in.
Width firing aisle, ft 25
Type of boilers ..... Stirling M-55
Number of boilers 12
Steam drums, three ..... 42 in. x 31 ft.; plate, 1 9/32 in.
Mud drum ..... 42 in. x 28 ft. 6 in.; plate, 1 15/32 in.
Tubes: Number of, 1156; dia. 3¼ in. hot rolled seamless; No. 8 gage, 300 lb.
Heating surface, sq ft 15,070
Superheater surface, each boiler, sq.ft 1,950

Superheater performance:

Rating of Boiler, Per Cent.	Superheat, Deg. F.
100	155
150	175
200	193
250	207
300	215

Grate surface (active), sq.ft 284
Heating surface per sq.ft. active grate area, sq.ft 53
Heating surface per sq.ft. superheater surface, sq.ft 7.7
Superheater surface per sq.ft. grate surface, sq.ft 6.86
Heating surface per installed kilowatt normal capacity of generators 2.94
Pressure, lb. per sq. in 275
Superheat, deg. F 175
Total steam temperature, deg. F 589.4

Coal analysis, temporary supply and upon which stoker performance is based:

Fixed Carbon	Volatile, Per Cent.	Moisture	Ash	Sulphur	B.t.u. per Lb.
56.74	29.00	4.23	11.13	2.58	13,500.

Coal analysis, permanent supply:

Fixed Carbon	Volatile, Per Cent.	Moisture	Ash	Sulphur	B.t.u. per Lb
35.7		1.5	3 to 5	0.8	15,000

Boiler settings (no arches) ..... Width, ft., 31, depth, ft., 21
Height, center of lower or mud drum to floor line ..... 7 ft. 9 in.
Insulating brick "Silocel," thickness, in 4.5
Firebrick ..... "Empire" (Missouri clay)
(Adamant cement used in boiler settings)
Estimated radiation loss, per cent 2.5
Combustion (furnace) volume per sq.ft. active grate area, cu.ft 11.6
Combustion volume per stoker retort, cu.ft 220
Combustion volume:

Boiler Rating Per Cent.	Pounds of Coal Fired per Hr. per Cu.Ft. Combustion Volume
100	1.53
150	2.23
175	2.64
200	3.06
250	4.15
300	5.56

Free area of opening in first pass, sq.ft 40
Free area of opening in second pass, sq.ft 30.6
Free area of opening in third pass, sq.ft 16.3
Free opening in first pass per sq.ft. active grate area, sq.ft 0.1409
Free opening in second pass per sq.ft. active grate area, sq.ft 0.108
Free opening in third pass per sq.ft. active grate area, sq.ft 0.0585
Stokers, type, Westinghouse underfeed, 15 retorts per boiler
Stoker drive, Morse type chain, motors, 13.5 hp. each, adjustable speed; 8 hp. at 200 r.p.m.; 13.5 hp. at 1500 r.p.m
Active grate area, sq.ft 284
Stoker performance (based on coal, 13,500 B.t.u. per lb., ash, per cent, 11.13):

Boiler Rating, Per Cent.	Combined Boiler and Furnace Efficiency, Per Cent.	Pounds of Coal per Retort per Hr. as Fired	Pounds Coal per Sq.Ft. Active Grate Surface	Volume of Air per Min. at 65 Deg. F. Cu.Ft.
100	74	336	17.75	16,500
150	76	491	25.90	24,500
175	75	580	30.60	29,000
200	74	674	35.50	33,500
250	68	914	48.10	45,000
300	61	1220	64.50	61,000

Continuous capacity of 235 per cent. boiler rating.
Four hours continuous at 275 per cent. boiler rating.

Coal Handling: Railway cars dump into crushers above coal bunkers
Crushers, two, Webster type, double-roll, capacity each, tons 100
Bunkers ..... Steel frame, concrete
Installed kilowatts per ton of bunker capacity, kw 14.7
No. of days storage at normal operation (4200 tons) 4.5
Bunker capacity per stoker retort, tons 23.4
Yard storage, tons, minimum capacity 25,000
Larries, four for each firing aisle, capacity each, tons 1
Larry capacity per stoker retort, tons 0.034
Conveyors, belt, four 24-in., capacity each, tons 100
Conveyor (belt) hourly capacity per stoker retort, lb. 4460 tons 2.23
Ratio conveyor hourly capacity to hourly capacity per stoker retort at 250 per cent rating 4.45:1
Capacity furnace ash hoppers, each, cu.ft. 850.5; cu.yd 38.8
Capacity ash cars, each, cu.yd 1.5
Soot blowers, Diamond type ..... 7 units on each boiler
Main steam valves ..... Jenkins type
Automatic stop valves ..... Edwards type
Blow-off valves ..... Gato type
Feedwater heaters, two, Cochran type, horizontal, capacity each, boiler hp 15,000
Water capacity, each heater, cu.ft 481
Heater capacity per rated horsepower capacity of boilers installed, boiler hp 1.67
Heater capacity per sq.ft. boiler heating surface, boiler hp 0.166
Feed Pumps ..... Worthington
Type, centrifugal, 5-in., four-stage, 750-gal. per min., 2650 r.p.m. driven by 250-hp. steam turbine

Feed Water Analysis:

	Grains per Gal.
Calcium carbonate	3.44
Magnesium	0.35
Magnesium sulphate	0.23
Magnesium chloride	0.23
Silica	1.11
Iron oxide and aluminum	0.41
Sodium and potassium chloride	0.82
Volatile and organic	1.29
	7.88
Suspended matter	1.92

Feed Water Treatment
Pounds of soda per 1000 gal 0.27
Pounds of lime (50 per cent.) per 1000 gal 0.55
Water softener, American, steel tank, tipper type, capacity, gal per hr 8,000
One cypress tank, dimensions, ft 16x18
Chimneys: Kellogg radial brick:
Two, 275 ft. x 14 ft., base diameter, 23 ft. 3 in.
One, 300 ft. x 18 ft., base diameter, 26 ft.
Coal burned per sq.ft., minimum cross-sectional area at 250 per cent. boiler rating (based on six 1500-hp. boilers to one 275 ft. x 14-ft. chimney), lb. per hr 534
Forced-draft fans: Green type No. 5 radial flow, double inlet, full housing, one for each boiler
Two motors to each fan, each 60 cycle, three-phase, 2200 volt, squirrel-cage induction type, one 40 hp., 875 r.p.m.; one 75 hp., 1170 r.p.m.
Performance:

Cu.Ft. per Min.	Static Pressure, In. Water	Horsepower	R.P.M.
25,500	3	17	720
40,500	5	49	1030
48,000	6	72.5	1170

Capacity per sq.ft. active grate, cu.ft. per min., minimum 95, maximum 176
Capacity per cu.ft. furnace volume, cu.ft. per min., minimum 8.2, maximum 15
Instruments for the boiler room
Recording steam meters, Bailey type, maximum flow at 300 lb., 175 deg. F. superheat, lb. per hr 56,200
12 type D-26, class 5 recording steam-flow, air flow and flue-gas temperature
12 type D-26, class 9 recording steam-flow, air-flow and speed of stokers
12 "Precision" three-in-one gages for air pressure in ashpit and last pass in boilers
12 electric indicating tachometers for stokers
2 standard-weight venturi meter tubes with type M register-indicator-recorder
2 double-extra-heavy venturi meter tubes with type M register-indicator recorder

TURBINES

Main turbine, Westinghouse
Type: cross-compound triple cylinder unit, pure reaction, parallel flow
Capacity: 60,000 kw. at 85 per cent. power factor, 60 cycle, three-phase, 12,200 volt
Peak load for short period, kw 70,000
Dimensions: Length 53 ft. 8 in., width 56 ft. 2 in. height 19 ft. 3 in.
Weight, total shipping, lb 2,600,000
Heaviest piece for crane, lb 142,000
Capacity per sq.ft. floor space covered by turbine, kw. (rated capacity) 20

Weight of turbine per rated kilowatt, lb. 43.34
Speed, high-pressure element, r.p.m. 1800, low-pressure elements, r.p.m. 1,200
Blading material: High-pressure element, phosphor bronze; low-pressure elements, phosphor bronze, except last three rows, which are elec. M. steel
Peripheral speed last row blading on low-pressure elements, ft. per sec. Tip speed, 608; Mean speed, 514
Main steam inlet 26 in. dia., supplied from two 18-in. headers
Total exhaust area, sq.ft. 452
Clearance, axial: High-pressure, in., $\frac{1}{2}$ in. min.: low-pressure elements, in., 5/16 min.
Clearance, tip: High-pressure, in. 0.045 to 0.055; low-pressure elements, in. 0.05 to 0.08
Bearing speed, ft. per sec., high pressure, 78.6; low-pressure 73.4
Unit load on main bearings, lb. per sq.in., high-pressure, 80; low pressure 124
Thrust bearing Kingsbury segmental
Normal oil circulation through main-bearings, gal. per min., each high-pressure, 10; low-pressure each 12.5
Normal oil circulation on each, thrust bearing, gal. per min. 20
Oil-cooler surface, total for both coolers, sq.ft. 1,200
Oil-cooler surface per kw. turbine capacity, rated, sq.ft. 0.02
Performance: Operating conditions, 290 lb. abs., 175 deg. F. superheat, when operating as complete expansion unit:

	Vacuum	
	29 In.	28.5 In.
Load	Pounds of Steam per Kw.-hr.	
30,000	11.05	11.55
40,000	10.75	11.15
50,000	10.55	10.90
60,000	10.75	11.10

When operating one high- and one low-pressure element

	Vacuum	
Load	29 In.	28.5 In.
	Pounds of Steam per Kw.-hr.	
30,000	12.1	12.45

When operating one low-pressure element alone on high-pressure steam

	Vacuum	
Load	29 In.	28.5 In.
	Pounds of Steam per Kw.-hr.	
20,000	14.0	14.45

Excitation: High-pressure generator, 90 kw., 240 volts; low-pressure generators, each, 115 kw., 240 volts
Main-unit capacity per kw. capacity excitation, kw. 187.5
Ventilation: Two air washers, capacity each, cu.ft. per min. 115,000
Three 60-cycle, three-phase, 2200-volt motor-driven fans, capacity each, cu.ft. per min. 75,000
Two 24-hp. motor-driven pumps, capacity each, gal. per min. 640

CONDENSERS

Type Westinghouse
No. of, four, condensing surface, each, sq.ft. 25,000
Tubes: Muntz metal; No. of, 5,285; diameter, in., 1; active length, 18 ft. 3$\frac{3}{4}$ in.
Weight of condenser with tubes, empty, lb. 220,000
Weight of condenser with tubes, full of water, lb. 405,000
Length of connection between turbine exhaust and condenser, ft. 30.5
Condenser support; hung from four keys fitting into exhaust connection and turbine steel foundation just under expansion joint at turbine exhaust
Lifting effect of vacuum at each exhaust opening, lb. 223,000
Tube surface per kw. of turbine served, sq.ft. 1.67
Circulating pumps, centrifugal Westinghouse type
Number of, 4; capacity each, gal. per min. 44,000
Drive, induction motor, 550 hp. 500 r.p.m.
Total pumping head, exclusive of head through condenser, ft. 9.0
Level of intake water below discharge water, ft. 3.5
Level of cold well below center line of pump, ft. 15
Circulating-pumping capacity per kilowatt, gal. per min. max., 2.94; normal 2.2
Circulating-pumping capacity per sq.ft. condenser tube surface, gal. per min., max., 1.76, normal 1.32
Circulating-pumping capacity per lb. steam condensed at consumption of 10.75 lb. per kw.-hr., 60 deg. F. water, lb. 136.5
NOTE: Circulating pumping capacity based upon four pumps of 44,000 gal. per min. each.

Condenser performance:

Lb. of Steam Condensed per Hr.	Circulating Water, Deg. F.	Vacuum, In. of Mercury
400,000	80	28.45
	60	29.15
	40	29.30
500,000	80	28.30
	60	29.05
	40	29.25
600,000	80	28.15
	60	29.00
	40	29.20

Intake: Open forebay with stop logs deflecting debris downstream
Discharge tunnel, concrete, square section
Intake screens: six Link Belt type, 78 in. wide, traveling
Each screen 6 ft. 4$\frac{1}{2}$ in. wide between centers of chains, 45 ft. long, speed, ft. per min. 9
Screen trays use No. 10. U. S. S. gage galvanized-steel wire cloth
Total screen capacity (water) at 12 ft. level, cu.ft. per sec. 515
Drive, two 10-hp. motors 865 r.p.m.
Total weight of screens, lb. p 131,000
Condensate pumps, capacity 400,000 lb. per hr. each, head, ft. 96
Submergence head, ft. 3.5
Drive, induction motor, 75 hp. 1750 r.p.m.
Air pumps: Le Blanc type, water requirements, gal. per min. 2,000
Suction lift, including friction, ft. 10
Discharge lift, including friction, ft. 4
Drive, induction motor, 100 hp. 700 r.p.m.
House turbines Westinghouse type
Two, 2000 kw. (2500 kv.-a.) 80 per cent. power factor, 60 cycle, three-phase, 2300-volt, 3600 r.p.m.
Pressure 275 lb., 175 deg. F. superheat, exhausting against back pressure of 5-lb. gage
Dimensions: Length, 24 ft. 5 in.; width, 9 ft. 10 in.; height, 6 ft. 10 in.
Weight: Total shipping, 81,000 lb.; heaviest piece for crane, lb., 9,000
Air washers: One of 8,000 cu.ft. per min., 60 gal. per min. pump, for each turbine

Performance:

Kilowatts	Power Factor, Per Cent.	Pounds Steam per Kw.-hr.
1200	80	28.1
1600	80	25.5
2000	80	26.6

Exciters (all exciters in the station)
One turbine-driven 300 kw., 250 volt d.c., 6000 r.p.m.
Performance of turbine:

Kilowatts	Pounds Steam per Kw.-hr.	
150	39.1	First nozzle
225	34.8	
300	34.3	Both nozzles
375	31.7	

One turbine driven, 50 kw., 125 volt, d.c.
Performance of turbine:

Kilowatts	Pounds Steam per Kw.-hr.	
25	48.8	First nozzle
37.5	40.2	
50	39.6	Both nozzles
62.5	36.0	

Two 300-kw., 250-volt d.c., 900-r.p.m. generators; 450-hp. synchronous motor
Two 50-kw., 125-volt d.c., 1175-r.p.m. generators; 75-hp. induction motor
Oil filtering system Richardson-Phenix Co.
One No. 438 Peterson type C filter, capacity, gal. per hr. 1,800
One No. 6 triplex oil pump, 3-hp. motor-driven, capacity, gal. per min. 30
One No. 12 type B filter, capacity, gal. per hr. 90
One No. 2 triplex pump, capacity, gal. per hr. 6
Pumps
Process pumps, for nitrate plant supply Allis-Chalmers type
No. of, 4, single-stage centrifugal, capacity, gal. per min. each at 200 ft. head 9,730
Drive, 700-hp. induction motor; efficiency, per cent 78
Domestic-supply pumps
Two 4-in. three-stage centrifugal; capacity, gal. per min. at 200 ft. head 350
Drive, 40-hp. induction motor, 1760 r.p.m.; efficiency, per cent 55
Fire pump, Allis-Chalmers Underwriters type; capacity gal. per min. 750
Two-stage, 4 in., 1750 r.p.m.; efficiency, per cent 64
Sump pump, 4 in. Wortbington type, vertical submerged, Class C volute, bronze impeller
Drive, 15-hp. induction motor, 1200 r.p.m.; capacity gal. per min. at 50 ft. dynamic head 500
Bus tunnel connecting power house with switch house, length 4000 ft.; tile brick and concrete
Buses carry power at 12,000 volts from generators to switch house for distribution
(Open transmission lines would be too seriously affected by carbide dust from electric furnaces)
Rotating field synchronous condenser Westinghouse type
Continuous rating at 0 per cent., leading power factor: kv.-a. input, 7500, volts 12,000
Ampere per terminal, 361; phase, 3; cycles, 60; poles, 12; r.p.m. 60
Safe operating temperature for embedded insulation, deg. C. 150
Exciter, kw. at 125 volts 60
Losses, including exciter losses, kw. 230
Disconnector switches; all are mechanically operated

drostatically tested to 450 lb. per sq.in.; the operating pressure will be 275 lb., and the superheat will be 175 deg. F. at 150 per cent. boiler rating. Francis E. Bradford, power engineer for the Air Nitrates Corporation, intends to gradually work up to a higher total steam temperature if experience shows this can be successfully maintained. The superheaters have 1950 sq.ft. of heating surface each, and the performance to be expected is given by the following figures:

Boiler Rating, Per Cent.	Superheat, Deg. F.
100	155
150	175
200	193
250	207
300	215

Of course the superheat will be affected by the operating conditions; that is, by secondary combustion in the superheater chamber, should it occur. If the excess air were reduced to a minimum, the superheat would be slightly lessened below that given when greater quantities of excess air were used.

The piping in the boiler room is well designed and put up. All piping is beneath the boiler-room floor, and the steam leads from the boilers drop down through the floor to the ring headers. It is always quite impossible to give figures on the steam velocities allowed for in steam piping without at length qualifying one's figures because the lines must be of sufficient area to pass very much more steam in emergencies than they normally pass when all mains are in service. The normal velocity will be about 9000 ft. per minute.

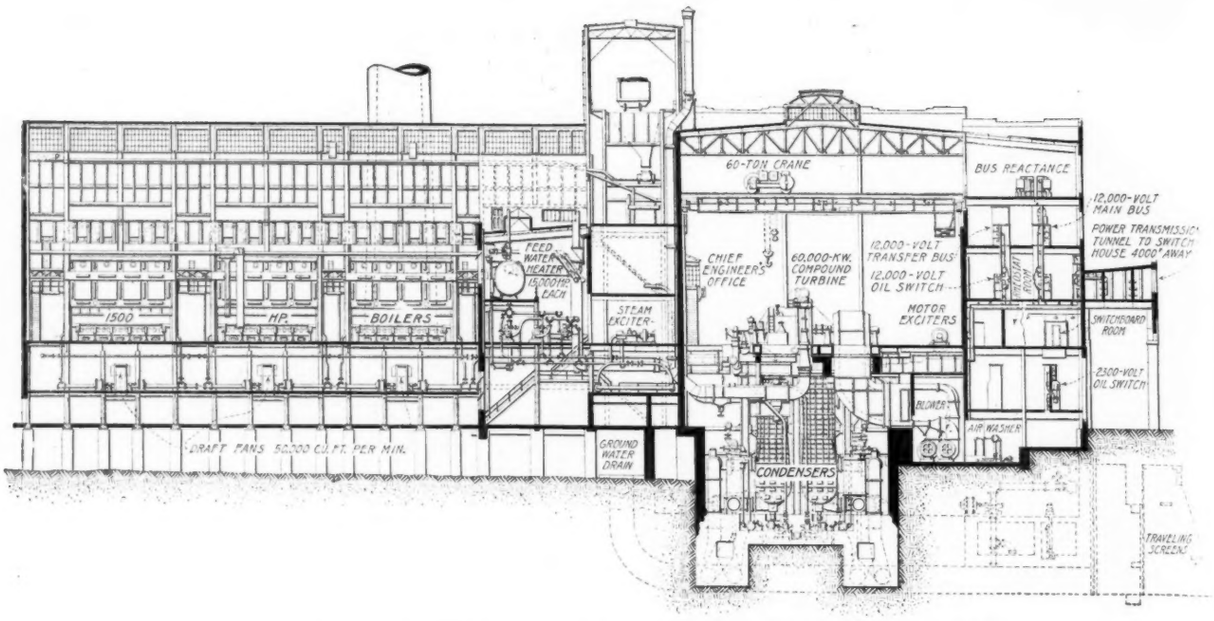


FIG. 7. CROSS-SECTIONAL VIEW OF THE POWER PLANT, LOOKING WEST

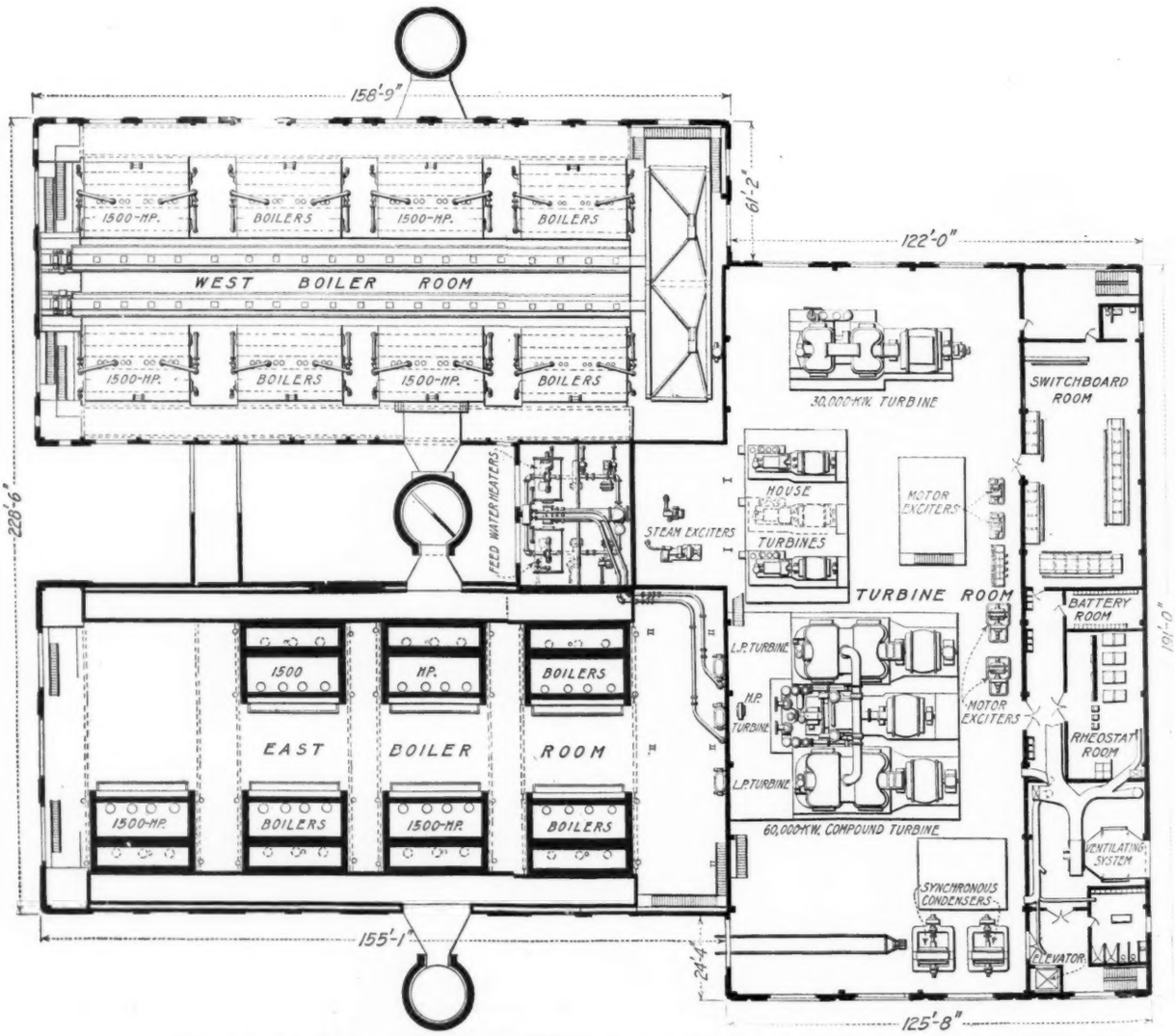


FIG. 8. PLAN OF THE STATION, SHOWING THE COMPLETE LAYOUT AS DESIGNED

Operation of the boiler room will be under the direction of a combustion engineer. All controls of stokers, draft fans, back dampers, and all indicating and recording instruments and gages are mounted on a board at the end of the boiler firing aisle. The chief engineer's office is situated so that one window bay fronts the main firing aisle and another looks out into the turbine room (see Fig. 7). A recording-gage board is installed in this office.

The J. G. White Engineering Corporation, New York, as subcontractors, designed and built the station under the immediate direction of F. E. Bradford, power engineer for the Air Nitrates Corporation; the architectural features were gone over by Ewing & Allen, architects, New York, and the Independence Bureau of Philadelphia made recommendations covering safety during construction and operation.

Other articles to follow relative to this plant are: The Main and House Turbines; The Condensing Equipment; Heat Balance Studies.

Green Cast-Iron Storage Hopper

To meet the varied objections to the use of wood, steel or reinforced concrete in storage hoppers, the Green Engineering Co., of East Chicago, Ind., has placed on the market a series of standard cast-iron hoppers to be used for the transfer of materials or for storage. Unit capacities range from 10 to 45 tons, and manifold hoppers composed of units can be furnished for any desired capacity.

FIG. 1. CAST-IRON HOPPER USED AS ASH-STORAGE TANK

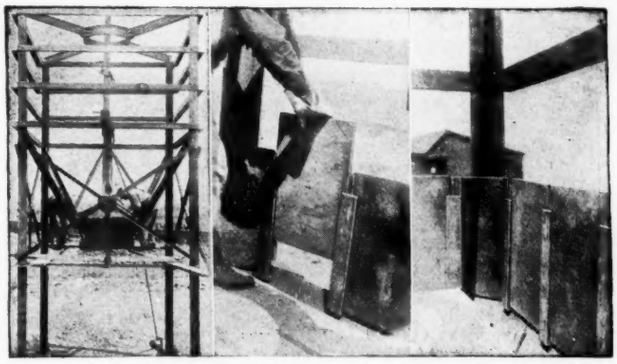


FIG. 2. ANGLE-IRON SUPPORTING STRUCTURE. FIG. 3. PUTTING CAST-IRON SIDE PLATES IN POSITION. FIG. 4. VIEW SHOWING CORNER CONSTRUCTION

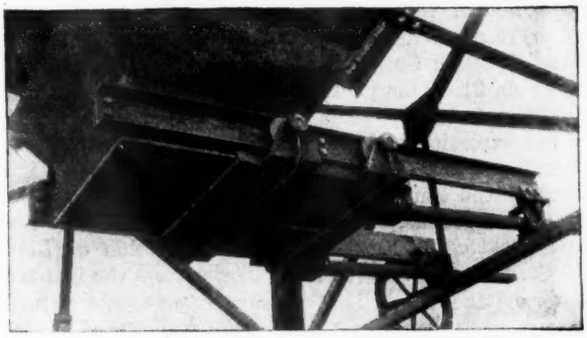


FIG. 5. CLOSE-UP VIEW OF DISCHARGE GATE

Sectional cast-iron plates make up the body of the hopper, which rests on a steel supporting structure of angle iron. This structure is built of standard steel sections cut and punched ready for erection and bolting. When it is in place the cast-iron plate supports are hooked upon the angle struts of the steel frame and into recesses in the sides of these supports are slipped the cast-iron side and corner plates. The plates and hooks are so constructed as to make tight joints.

At the bottom is a substantial hopper gate designed for quick discharge and large enough to offset any arching tendency of the material handled. The gate is mounted on rollers and is actuated by means of racks and a chain-operated pinion gear. The gate can be mounted so that the chain will come on any one of the four sides.

In the power plant the hopper is adapted for the storage of ashes, particularly from steam-jet vacuum conveyors, sized coal and screenings. In Fig. 1 the hopper is used for ash storage. Fig. 2 shows the supporting frame. In Fig. 3 the cast-iron side plates are being placed in position. Fig. 4 shows the corner construction and Fig. 5 is a close-up view of the discharge gate.

One of the outstanding advantages claimed for this hopper is the ease and quickness of erection. The frame is made of standard parts which are bolted together and the cast-iron plates are slipped into place, so that no skilled labor is required in the assembly work.

The rusting and corrosion of cast iron is negligible, and the comparatively thick metal in the plates resists the abrasive action of the material stored.

BOILER EXPLOSION AT MOBILE

ONE of the most disastrous boiler explosions in recent years occurred at the plant of the Mobile Electric Co. at Mobile, Ala., at 8:20 p.m., Friday, Feb. 21. This plant furnishes power and light for Mobile and vicinity. The total property damage, caused by the explosion and the fire that ensued, will be considerably in excess of $100,000. Three persons were killed at the time of the explosion, and one death has since occurred as a result of the accident.

The station is located at the intersection of Royal and St. Louis Sts., about three blocks from the business center of the city. That passers-by were not injured appears remarkable considering the violence of the explosion and the amount of material projected into the two thoroughfares. A pair of 12-in. I-beams 20 ft. long and two very heavy 15-in. I-beams 25 ft. long were thrown entirely across Royal St., one of these cutting off the corner of a foundation stone and being projected partly into a store on this street.

The plant was like those so frequently found where the capacity to be required was not anticipated in the original construction and additions had been made from time to time. This had resulted in a distinct division in the plant as regards both boiler equipment and generating units. One part was of modern construction with modern equipment. The old plant, the portion in which the explosion occurred, comprised the haphazard arrangement of apparatus incident to the unforeseen needs of development referred to. A solid brick wall 26 in. thick, pierced only by the necessary door openings, divided these two sections. The fact that this wall offered considerable resistance to the force of the explosion and presented, as well, a formidable fire barrier no doubt saved the plant from total destruction.

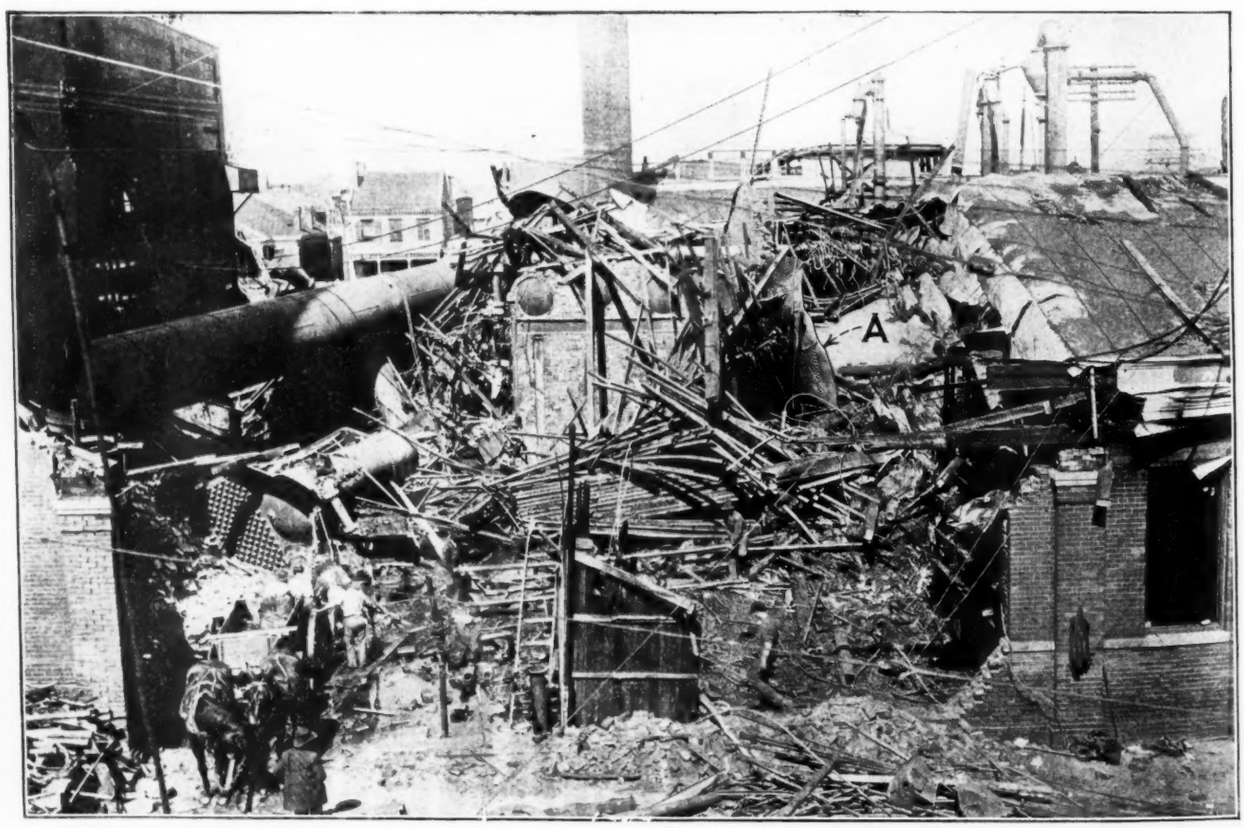


FIG. 1. LOOKING NORTH FROM ST. LOUIS ST. UNINJURED HEINE AT LEFT IN FRONT; UNINJURED STIRLING NO. 7 IN CENTER

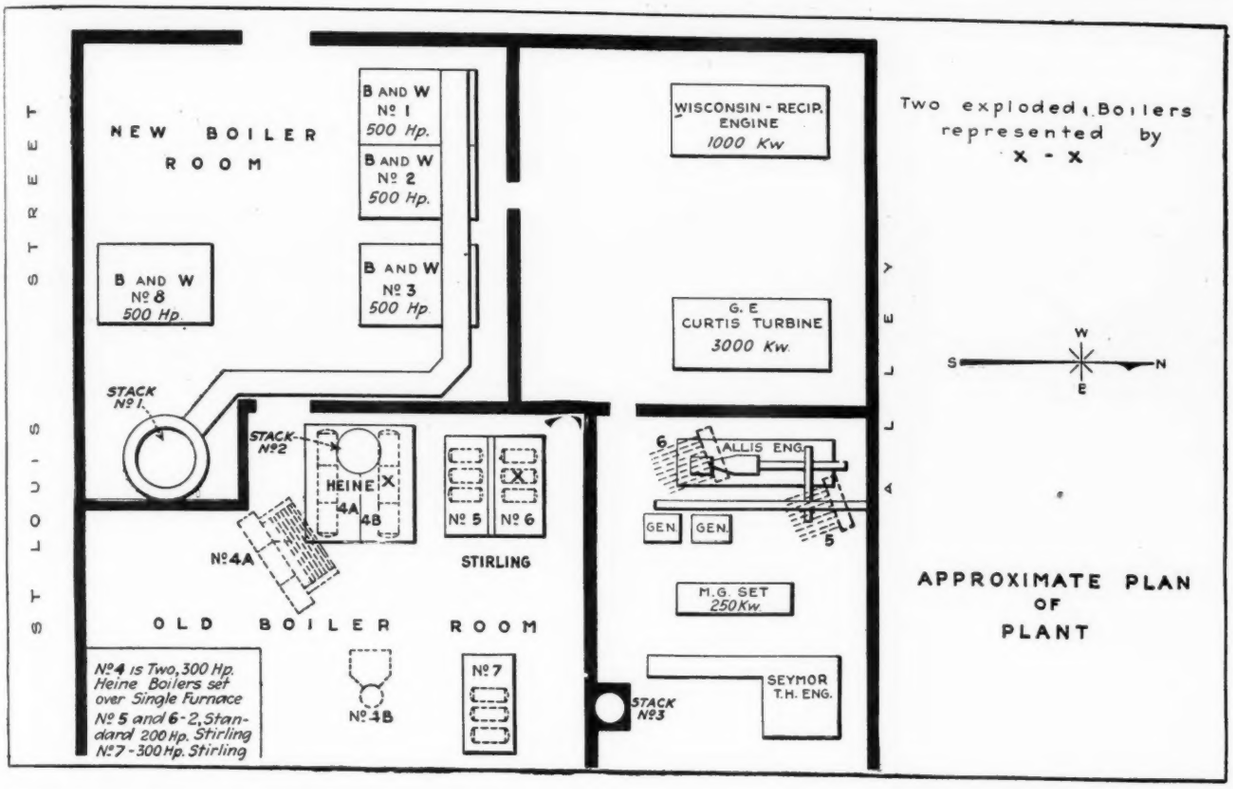


FIG. 2. PLAN OF PLANT AND GENERAL VIEW OF RUINS FROM THE CORNER OF ST. LOUIS AND ROYAL STS.

The accompanying plan, Fig. 2, shows roughly the arrangement of the principal units. In the new boiler room were four Babcock & Wilcox boilers, three of 500-hp. capacity, stoker-fired, known as Nos. 1, 2 and 3, and a detached boiler of the same type, of 600-hp. capacity, known as No. 8.

The boiler equipment in the old plant was composed of a pair of Heine boilers, containing 163 3½-in. tubes 18 ft. long with single 48-in. drums and two 200-hp. standard Stirling boilers containing 180 tubes each, known as Nos. 5 and 6. There was also a detached standard Stirling boiler, of 300-hp. capacity, known as No. 7, in the old plant. The two Heine boilers were set over one furnace and operated as a single unit, know as boiler No. 4. These boilers were connected on the steam side without the intervention of valves, but were not so connected below the water line. Each was supplied with a separate water column and fed as an independent boiler. At the time of the accident, boilers Nos. 5, 6 and 7 were not generating steam although still connected to the line, as the peak load had been passed and the fires under them were allowed to burn down. These boilers would probably have been disconnected from the line in a short time. The pressure as shown by the recording gage was just above 160 pounds.

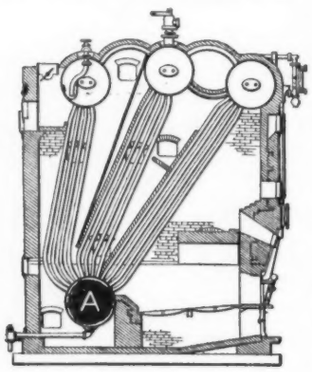


FIG. 3. STIRLING BOILER, SHOWING LOCATION OF RUPTURED HEAD

The two Heine boilers, No. 4, were also working light and the main part of the load was being carried by the B. & W. boilers in the new plant, with the exception of No. 3, which was being retubed.

The two stacks, shown on the plan as Nos. 2 and 3, in the old plant, were connected by a flue, so that either stack could serve all the boilers in the old plant or, by manipulating the dampers, the load could be divided between these stacks.

All boilers in the new plant were served by stack No. 1, which was of concrete; Nos. 2 and 3 were of plate steel. Only stack No. 2 was affected by the explosion, it being thrown down across the No. 5 and 6 Stirling boilers, as shown in the general view of the ruins, Figs. 1 and 2. The No. 7 Stirling boiler, in the old plant, was practically undamaged, although covered with débris, as will be seen in the center of Fig. 1, and also at the right end of the prostrate stack in Fig. 2.

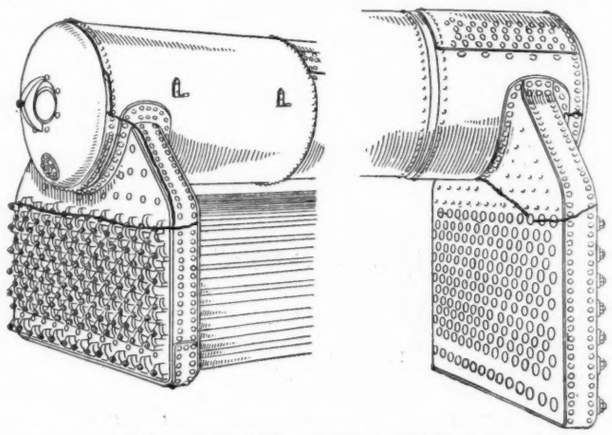


FIG. 5. REAR OF HEINE BOILER, SHOWING APPROXIMATELY THE LINES FOLLOWED BY THE FRACTURE

Two boilers exploded—the northern unit of the pair of Heines, No. 4, and the northernmost, No. 6 of the pair of Stirlings. These are indicated by X's on the plan, Fig. 2. The pressure carried was 160 lb. and the recording pressure gage showed that this had not been seriously exceeded.

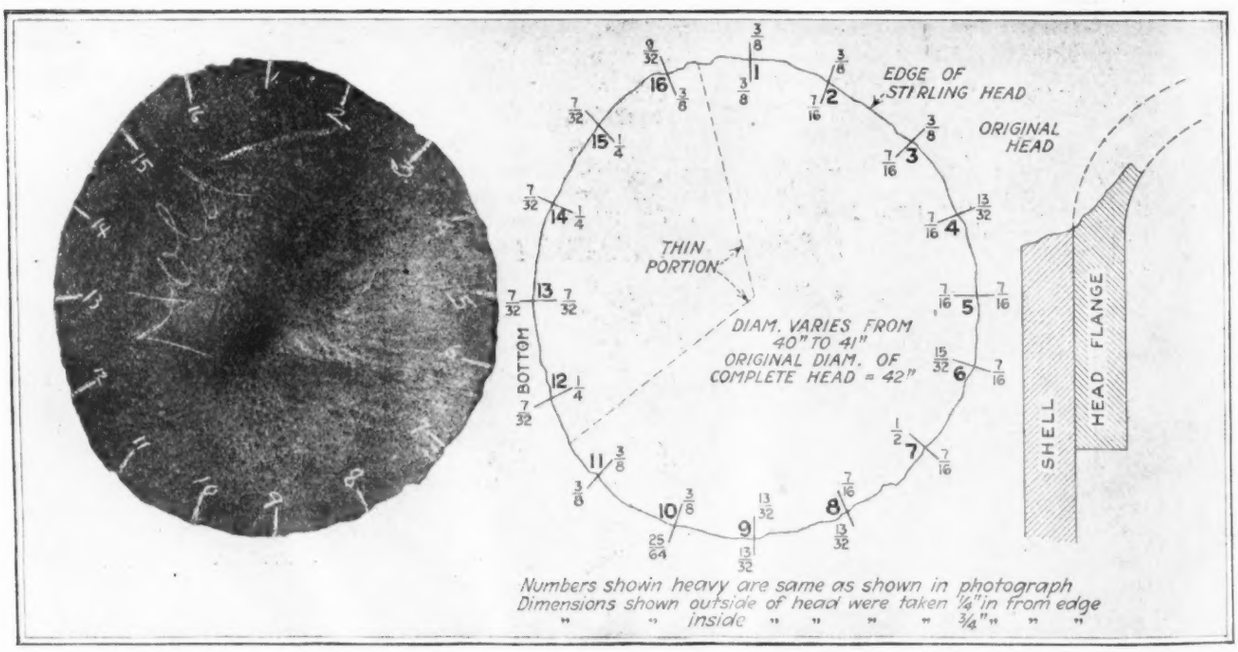

EDGE OF STIRLING HEAD
ORIGINAL HEAD
THIN PORTION
DIAM. VARIES FROM 40" TO 41"
ORIGINAL DIAM. OF COMPLETE HEAD = 42"
BOTTOM
SHELL
HEAD FLANGE
Numbers shown heavy are same as shown in photograph
Dimensions shown outside of head were taken ¼" in from edge
" " inside " " " " ¾" " " "

FIG. 4. DISK FROM EXPLODED STIRLING MUD DRUM, SHOWING REDUCTION OF THICKNESS BY CORROSION. THE THIN PART WAS AT THE BOTTOM AS THE DRUM LAY IN THE SETTING

The Stirling boiler was 22 years old. It failed by blowing out the head on the southern end of the lower

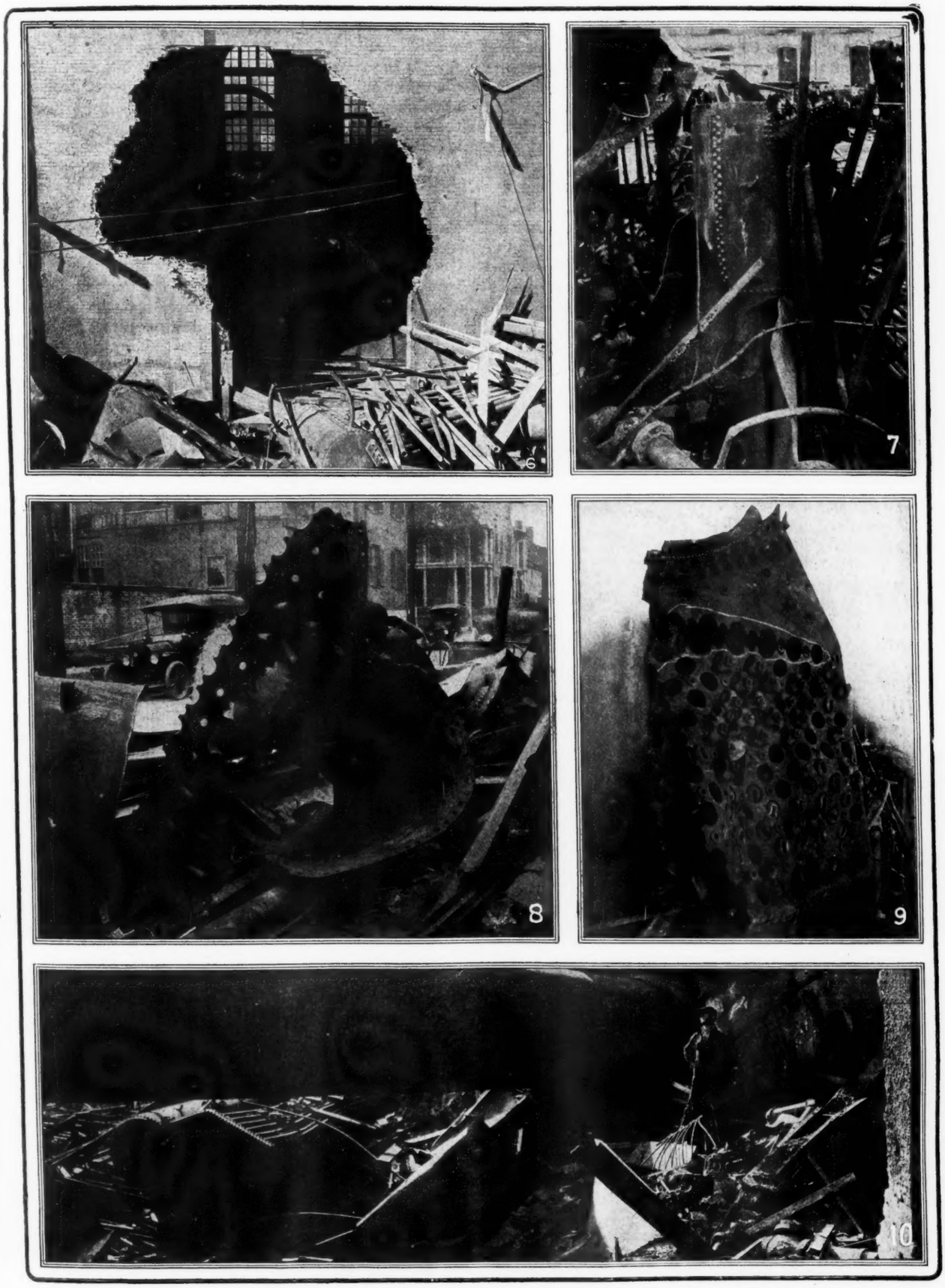


FIG. 6. STIRLING DRUMS AT BASE OF BREACH IN DIVISION WALL. FIG. 7. EXPLODED HEINE BOILER. FIG. 8. FRACTURE THROUGH REAR TUBE SHEET. FIG. 9. FRACTURE OF FRONT TUBE SHEET. FIG. 10. VIEW FROM INSIDE NEW BOILER PLANT, LOOKING OUTWARD UNDER FALLEN STACK. UNEXPLODED HEINE AT LEFT

or mud drum, the head marked *A* in Fig. 3. This was a 42-in. drum, and the head was unstayed but bumped to a radius of about 60 in. A disk broke out clean at the crown of the flange. Fig. 4 shows a photograph of this disk, and the sketch alongside shows the thicknesses as calipered one-quarter and three-quarters of an inch from the edge at the points indicated. The original thickness was less than would be required by the present A. S. M. E. Code, which would be five-eighths in. for 160 lb. if the radius of curvature of the head was 60 in. The code prescribes that the corner radius shall not be less than 1½ in. nor more than 4 in. and within these limits not less than 3 per cent. of the radius to which the head is bumped. We have not learned the corner radius in this case, and regret that no photograph was procurable of the ring of the flange out of which this disk was broken.

Fig. 2 shows two breaches in the eastern wall of the old station, the larger to the right of the concrete stack and the smaller still farther to the north. The No. 6 Stirling boiler stood in front of the smaller of these openings, which was evidently caused by its explosion. This boiler was projected to the north and landed on top of the 300-kw. Allis reciprocating unit. No. 5 Stirling apparently did not explode. None of the shells was ruptured, but a great many of the tubes had been pulled out of the drums and the drums had been separated from each other. They were projected in the same direction as those of No. 5. Some Stirling drums are shown at the base of the breach in the wall in Fig. 6, but it is not plain which of the boilers they came from. All of the Stirling drums, with the exception of that from which the disk shown in Fig. 4 broke out, were found intact. The closed head, that is the head without a manhole, of the mud drum of the No. 5 Stirling was in line with that which exploded and within a few inches of it in the division wall. This position made the inspection of these heads difficult and the determination of the corrosion by drilling impracticable. This head was found intact and not corroded. Inspection of the corresponding head in boiler No. 7 revealed corrosion, and a new head has been put in.

The northernmost of the pair of 15-year old Heine boilers, comprising Unit No. 4, exploded by breaking off the rear drum head and the back water-leg. The line of fracture passed through the tube holes, hand holes and adjacent stay-bolt holes of the upper row of tubes approximately as shown in Fig. 5. This water-leg was hurled backward against the division wall, evidently causing the larger breach, while the drum with the front leg and some of the tubes still attached was thrown forward and up-ended in the position shown at *A* in Fig. 1 just to the right, in that picture of the uninjured Stirling. The boiler, still in this position but viewed from the other side, is shown in Fig. 7 with a small portion of the rear water-leg attached, the end carrying the front water-leg being buried in the débris. The drum fracture runs through the solid sheet, passing through the girth seam without being diverted.

Fig. 8 shows the same piece viewed endwise after it had been removed to the side of the station. The fracture was along the line indicated by the chalk mark. Fig. 9 shows a portion of the front head after it had been cut away from the shell. Here the fracture is also indicated by chalk lines. There is no evidence of crystallization or corrosion in any of these fractures and the metal between the ligaments shows a good percentage of reduction. Some broken stay-bolts had been replaced six months before the explosion, but none was in evidence. The unexploded Heine was thrown to the left in the position indicated upon the plan, Fig. 1, lying as shown in Fig. 10, taken from inside the old station, looking eastward under the fallen stack. It was apparently injured only by the bending of some of its tubes and will be put back into service. Fig. 11, the rear head of the Heine drum, shows how the throat sheet was bent backward and the line followed by the fracture indicated in Fig. 5. The enlargement of the stay-bolt holes by the tearing out of the bolts is apparent. The throat stays broke in the shank, both through and outside of the rivets.

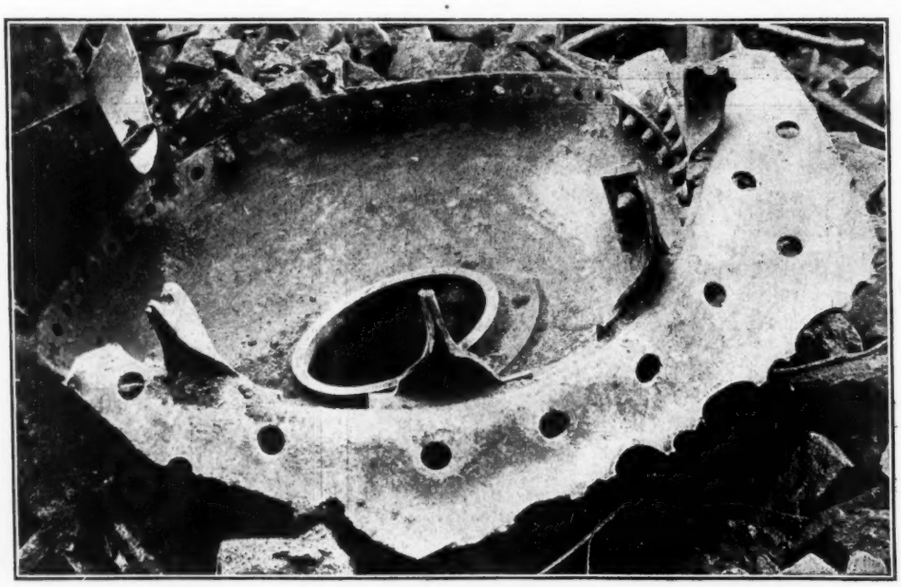


FIG. 11. REAR HEAD FROM HEINE DRUM, SHOWING BACKWARD BENDING OF THROAT SHEET AND THE WAY THE THROAT STAYS WERE TORN OFF

The necessity of getting the station back into operation led to the disturbance of much of the débris and the moving of parts the identification and location of which would have been of importance in determining the cause and manner of the explosion before expert observers had an opportunity to study their positions and fractures. Many of the pieces shown have been cut apart with the torch. For example, the piece shown in Fig. 9 is one-half of the front water-leg of the Heine. It had been removed from the position shown in Fig. 7, where it was attached to the drum and buried in the débris, and not only cut loose from the shell but cut in halves vertically. We have tried in such cases to indicate the original fracture by chalk lines.

There is much speculation as to which of the boilers let go first. Letters from the builders of both the Heine and the Stirling will be found on pages 465 and 466.

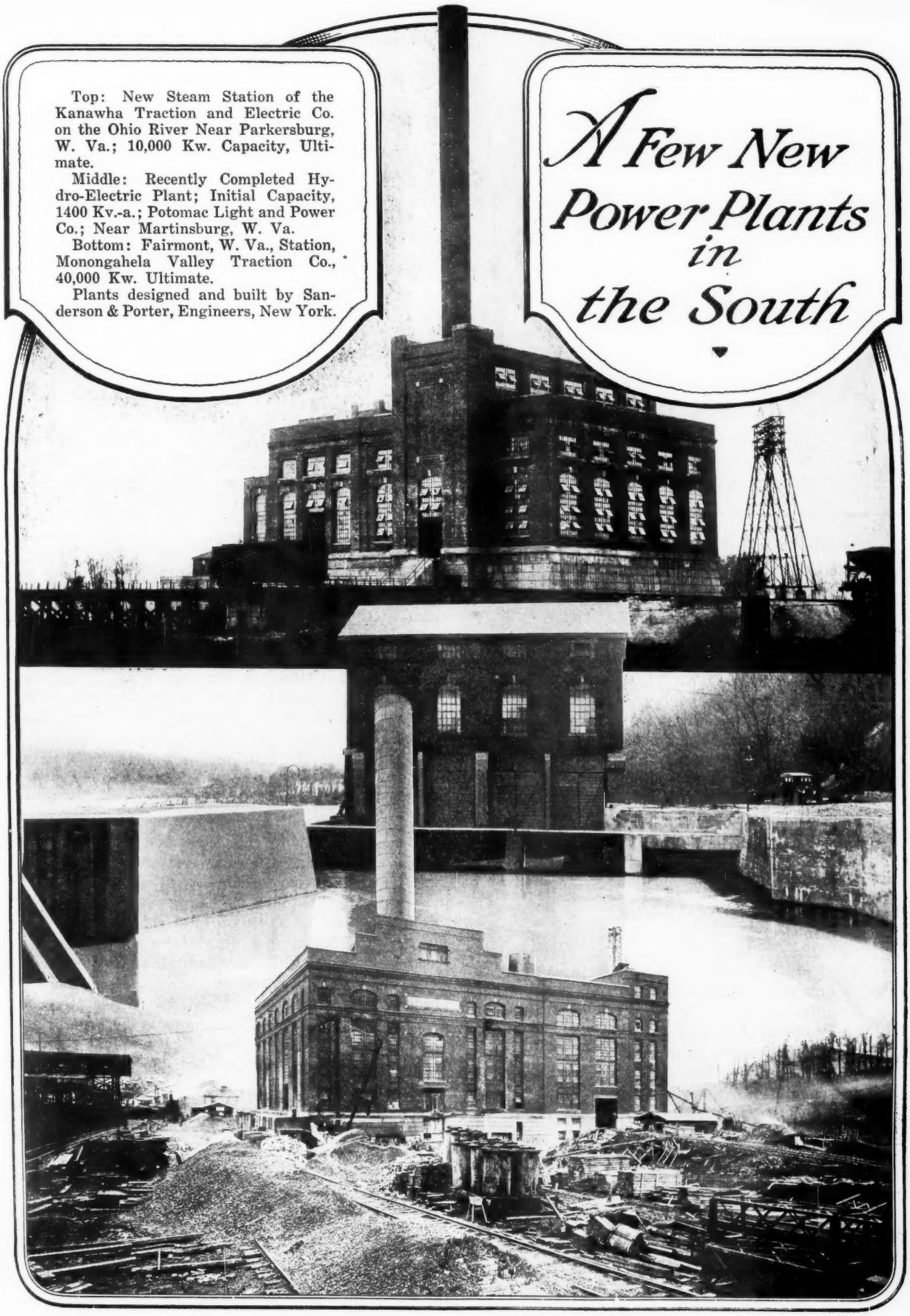
A Few New Power Plants in the South

Top: New Steam Station of the Kanawha Traction and Electric Co. on the Ohio River Near Parkersburg, W. Va.; 10,000 Kw. Capacity, Ultimate.

Middle: Recently Completed Hydro-Electric Plant; Initial Capacity, 1400 Kv.-a.; Potomac Light and Power Co.; Near Martinsburg, W. Va.

Bottom: Fairmont, W. Va., Station, Monongahela Valley Traction Co., 40,000 Kw. Ultimate.

Plants designed and built by Sanderson & Porter, Engineers, New York.



The APPALACHIAN POWER SYSTEM

By

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Describes the chief features of the Appalachian Power Company's hydro-electric and steam system supplying electric current to a large section of the South.

THE southwestern part of Virginia and the southeastern section of West Virginia possess in large quantities such natural products as coal, manganese, zinc, iron, salt, limestone, alkalies, silica and gypsum. The great semibituminous or Pocahontas coal fields are here. Electrification of many of the coal mines has assisted in increased production, and, as this electrification uses water-power-generated electricity for the most part, which is produced more cheaply than the usual steam station can furnish it, conservation of the high-quality coal mined in the district is accomplished. Power is supplied this district by the Appalachian Power Co., which began development of two of its several power sites in 1911.

The hydro-electric developments are located on the New River, which rises in the northwestern part of North Carolina and flows in a general northerly direction through the States of Virginia and West Virginia. It drains the territory which has the highest altitude of any part of the country east of the Rocky Mountains and in which the annual rainfall is from 45 to 60 in. The drainage basin contains numerous springs and is heavily wooded.

The Appalachian Power Co. owns several hydro-electric power sites, two of which have been developed, and also controls a reservoir site above the power developments. The building of this reservoir and the consequent regulation of the river will greatly increase the output of hydro-electric power and improve operating conditions.

The two plants now developed are known as No. 2 and No. 4. They are about 50 miles southeast of the coal fields on a branch of the Norfolk & Western Ry. and have a combined rating of 30,000 hp. They are similar in design and the turbines are identical in size and characteristics, but run at different speeds to suit the different heads.

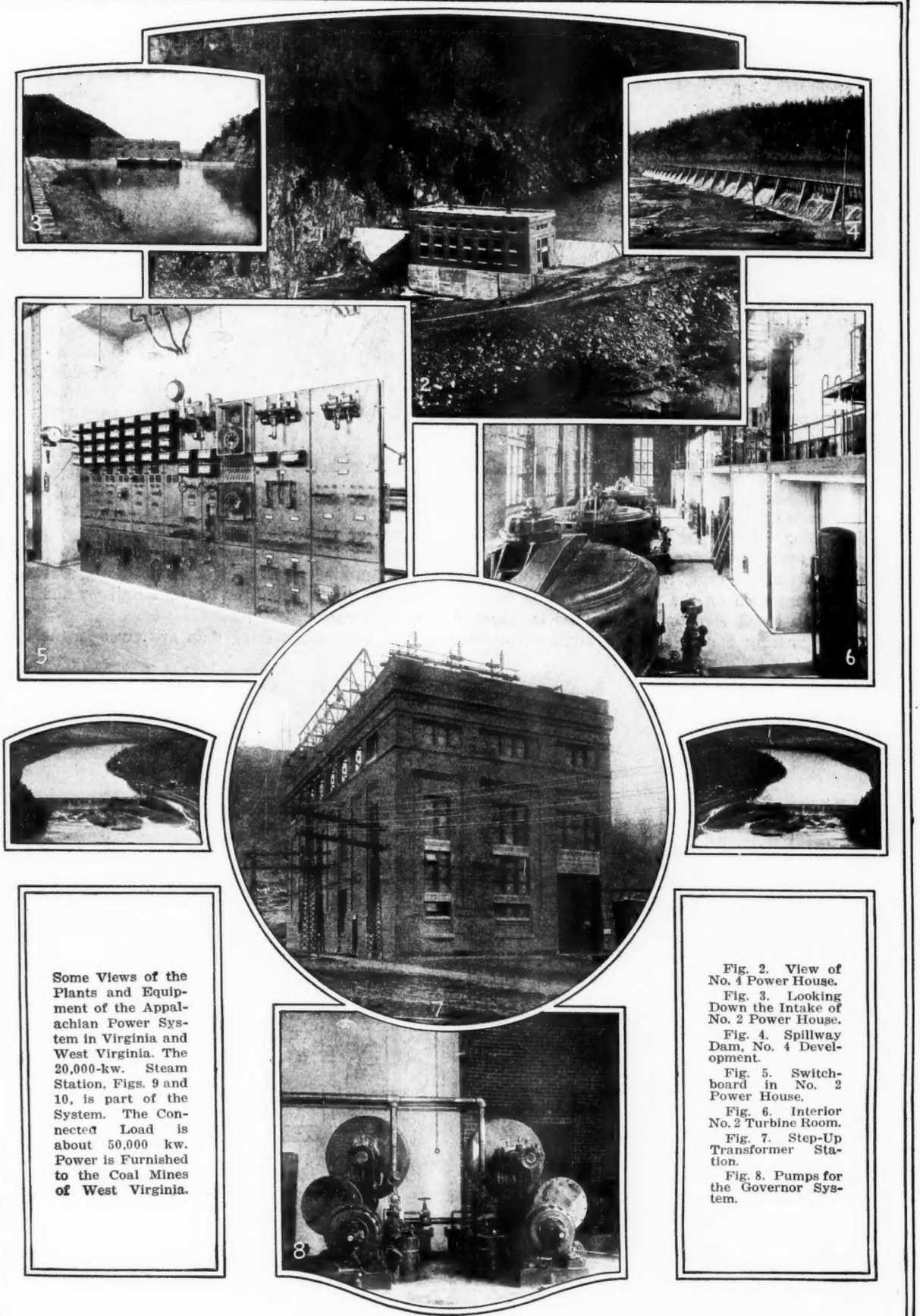
The substructures are of reinforced concrete and were the first of the improved concrete form scroll ases of the type which is now so generally used for medium and low head developments.

The spillway dams are of the ogee type of solid masonry. Provision has been made on the spillway sections of the dam for flashboards, and as the river rises very rapidly in flood times, a quick-acting catch holding the sections is used to insure a quick and positive release. To provide for ordinary freshets six motor-operated Tainter gates of standard type were installed on each dam.

In conjunction with the main spillway dam at No. 2, there is an auxiliary spillway made by enlarging a natural channel and the ordinary flow shut off by a low barrier dam and flashboards of similar design to those of the main spillway. The power-house substructure forms part of the dam, and the waterways, including scroll cases and draft tubes, are formed in the concrete, into which are built the speed ring and pit liners. The runners are of cast iron and the turbines, which were guaranteed for 85 per cent. efficiency, at test showed a maximum of 93.7 per cent., which is probably the highest efficiency ever obtained in hydraulic-turbine practice.

The generators are direct-connected through the vertical shaft to the turbines, and the weight of the revolving parts is sustained by roller and Kingsbury bearings on top of the generators. Governors are of the hydro-electric double floating-lever type, operated by high-pressure oil.

Exciters are the vertical type, of which there are two in each station. The power is generated at 13,200 volts and transmitted to the main transformer station, which is near No. 2 development. This transformer station was designed to take care of not only the two plants developed, but also the several additional plants



Some Views of the Plants and Equipment of the Appalachian Power System in Virginia and West Virginia. The 20,000-kw. Steam Station, Figs. 9 and 10, is part of the System. The Connected Load is about 50,000 kw. Power is Furnished to the Coal Mines of West Virginia.

Fig. 2. View of No. 4 Power House.

Fig. 3. Looking Down the Intake of No. 2 Power House.

Fig. 4. Spillway Dam, No. 4 Development.

Fig. 5. Switchboard in No. 2 Power House.

Fig. 6. Interior No. 2 Turbine Room.

Fig. 7. Step-Up Transformer Station.

Fig. 8. Pumps for the Governor System.

when they are built. The location is near the center of the present and future developments, and it is used as the central transforming and load-dispatching station. The electrical apparatus in the power house is simple and consists of low-tension busses, switches and station transformers, all of the high-tension apparatus being in the transformer station. The power is transmitted on duplicate high-tension lines at 88,000 volts and at 13,200 volts on the low-tension distribution lines. Two general styles of structures were used for supporting the lines. The single-pole, wishbone type, and the double-pole strain structures were used on the first lines, while in later construction two-pole structures were used throughout, with extra bracing for strain and angle structures.

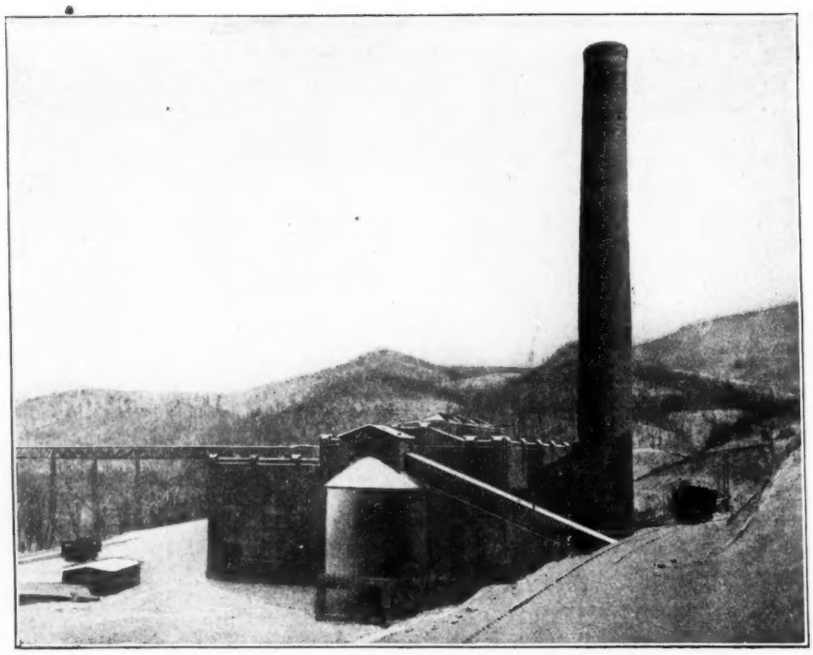


FIG. 9. THE NEW STEAM STATION AT GLEN LYN, VA.

copper conductors are employed. Throughout the territory served there are six high-tension substations with step-down transformers, high- and low-tension switching apparatus, lightning arresters, etc., from which the power is distributed to the consumer at 13,200 volts and to those near at hand at voltages suitable for their requirements. In conjunction with the hydro-electric plants the company operates several auxiliary steam plants, the largest of which is the Glen Lyn station.

Besides this auxiliary steam plant the system is interconnected with the Norfolk & Western steam station at Bluestone and the Roanoke Railway and Electric Co. at Roanoke.

The chief engineering data are given in the two accompanying tables, which cover both the water power and the steam stations.

Besides having several steam plants upon which to fall back when water power is insufficient, the company

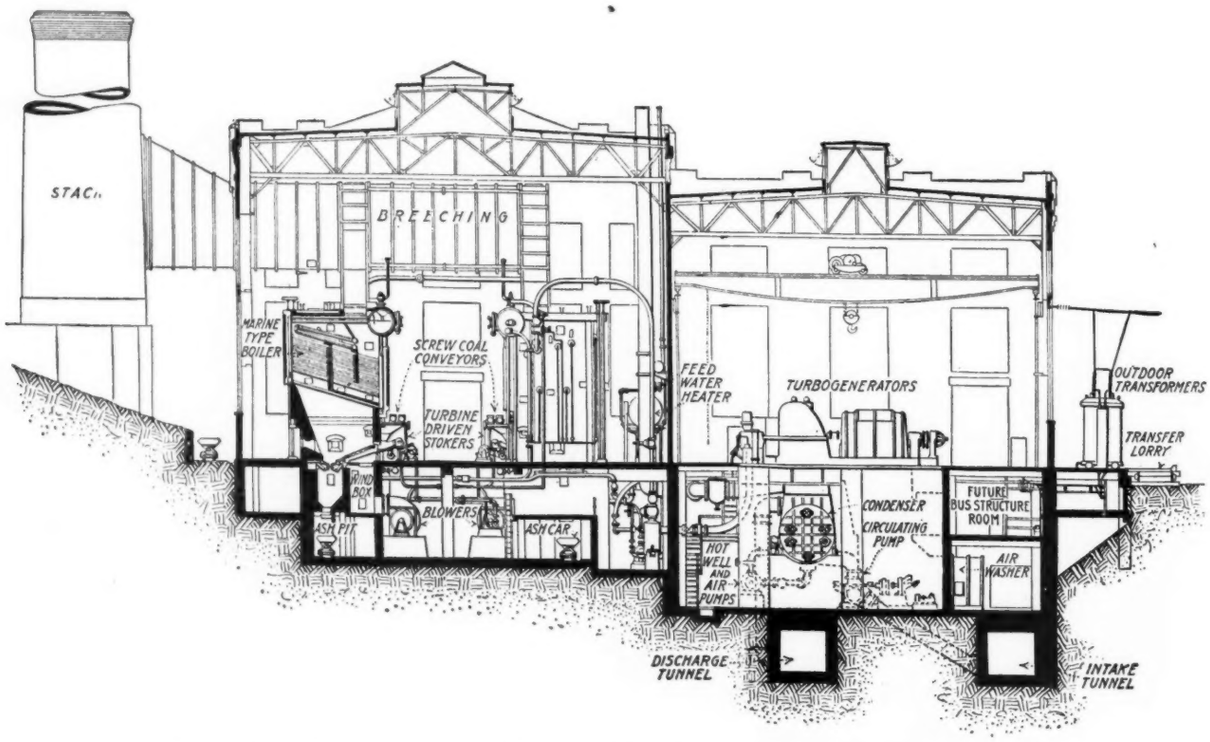


FIG. 10. SECTIONAL VIEW OF THE 20,000-KW. STEAM STATION AT GLEN LYN, VA.

Latticed steel poles designed to act as strain structures are used at all railroad crossings. Suspension-type insulators are used throughout, and telephone circuits are strung on the same poles. Both aluminum and

is interconnected with the Roanoke Railway and Electric Co. at Roanoke, Va., and also with the Norfolk & Western Ry.'s steam plant at Bluestone, W. Va. The latter connection is made through a frequency changer.

The total connected load of the Appalachian company system is approximately 50,000 hp. With scientific management the interconnection have made it possible for the power company to meet the unprecedented demand from the coal fields and industrial plants in all parts of the area. In 1917, however, in order to meet the rapidly increasing load and to do all possible to prevent the threatened coal shortage, the company decided to build an additional steam auxiliary plant. Such a station was decided on because it could be completed

IMPORTANT DATA, APPALACHIAN WATER-POWER STATION

	Power House No. 2	Power House No. 4
Main-Unit Turbines:		
Head without flashboards	48.5 ft.	34.0 ft.
Number	4	3
Rated capacity	3500 hp.	6000 hp.
Type, Francis, single-runner inward-discharge,	concrete formed	scroll case
Diameter of runner	7 ft., 6½ in.	7 ft., 6½ in.
Diameter of shaft	14½ in.	14½ in.
Operating speed	116 r.p.m.	97 r.p.m.
Specific speed	309	312
Guide bearings, Babbitt-metal lined		
Thrust bearings, standard roller and Kingsbury		
Exciter Turbines:		
Head without flashboards	48.5 ft.	34 ft.
Rated capacity	430 hp.	250 hp.
Type, Francis, single-runner, inward discharge,	cast-iron scroll case	
Diameter Runner	2 ft., 3⅜ in.	2 ft., 3⅜ in.
Diameter shaft	4½ in.	4½ in.

Main Generators:

Dev. No. 4 type A.T.B. 74-2300-97-13,200-vertical internal revolving field, rated capacity, 2300 kv.-a. @ 97 r.p.m., 13,200 volts, 60 cycles.

Dev. No. 2, A.T.B. 62-4000-116-13,200 vertical internal revolving field, rated capacity, 4000 kv.-a. @ 116 r.p.m. 13,200 volts, 60 cycles.

Exciter Generators:

Dev. No. 2, M.P.C. 6-250-400-250 vertical revolving-armature type, rated capacity 250 kw. @ 400 r.p.m., 250 volts.

Dev. No. 4, M.P.C. 6-150-330-250, rated capacity 150 kw. @ 330 r.p.m., 250 volts

Main-Unit Governors:

Hydraulic type of oil pressure—double floating lever, for both developments.

Exciter Governors:

Hydraulic type of oil pressure.

Oil Pumps for Governor Oil:

Triple back-geared, motor-driven.

Main Gates:

Steel plate, built-up-roller, double-screw, motor-operated.

Crane:

50 ton, 4-motor with 10-ton auxiliary hook.

Main Step-Up Transformer Station:

Transformers, W.C.D. 60-6000-88,000-13,200 water-cooled oil-insulated type normal rating, 6000 kv.-a @ 88,000 volts delta on high-tension side; 13,20 volts on low-tension side 60 cycles.

High-Tension Switches:

K-10-110,000 volts solenoid-operated.

Lightning Arresters:

Aluminum-cell, electrolytic.

in a shorter period than a hydro-electric plant and furthermore, because it would permit the utilization of the maximum water-power and allow operation of the system at its maximum efficiency. In other words, it is intended to use as much hydro-electric power as possible without counting on storage, depending upon the steam auxiliary in times of low water. Later it is planned to build a third hydro-electric plant for the next source of power and follow this with another steam unit, and so on.

The construction of a 20,000-kw. station with an ultimate rating of 60,000 kw. was started in September, 1917, at Glen Lyn, Va., which site is the nearest of the coal fields at which an adequate supply of water suitable for condensing purposes was available. It has the additional advantage of being on the main lines of the Norfolk & Western Ry. and the Virginian Ry. Simplicity was the keynote of the design, ease and economy of operation and ample space for apparatus being other ruling considerations.

A coal siding leads from the Norfolk & Western main line to a point back of the boiler room. In the future another siding will run from the Virginian Ry. to practically the same point but higher in elevation. When desired, coal may be stored on the ground paralleling these sidings and rehandled by a locomotive crane.

From the cars the coal will be dumped into a steel track hopper and by means of plate feeder and grizzly fed to a crusher driven by a 25-hp. induction motor, all of which apparatus is housed in a reinforced-concrete building. The fine coal is taken by means of a Robbins belt conveyor, rated at 50 tons per hour, to a reinforced-concrete coal bunker of 800 tons capacity outside of the boiler room. The bunker proper is circular in form and has 12-in. very heavily reinforced walls. Crickets with a 45-deg. slope made of hollow tile for lightness, with a smooth concrete cover, lead the coal to the four bottom gates.

This type of bunker has several advantages over the

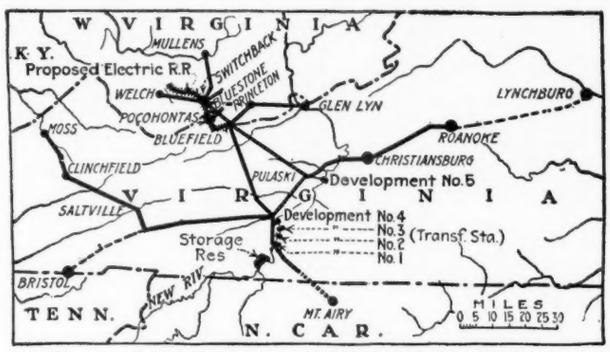


FIG. 11. DISTRIBUTION SYSTEM AND LOCATION OF POWER HOUSES

bunker suspended in the boiler room: It permits of much lighter superstructure steel in the boiler room, allows an unobstructed passage for the breeching, makes a lighter, better-ventilated boiler room, and can be constructed without interfering with the erection of boilers and other apparatus at a time when the boiler room is necessarily much crowded.

To convey coal from the bunker to the boiler furnaces use is made of four screw conveyors, each of them capable of delivering 25 tons per hour and driven by two 25-hp. adjustable-speed motors. More than one conveyor can serve each boiler, hence breakdown of one conveyor will not cripple a boiler. The motors and driving gear for the conveyors, also a small motor-generator set furnishing direct current for magnetic separators (used to clean coals), are housed under the wood structure covering the bunker.

The generator and boiler room floor was fixed about 6 ft. above the high-water mark of the year 1916, and the reinforced-concrete substructure was made with 10 per cent. of hydrated lime to make the walls impervious to water. Open drains will lead water which may seep through the walls to a sump in the power house from which it is removed by motor-driven centrifugal pumps. The superstructure walls are of hollow tile, which will be stuccoed when the next unit is added. Gypsum slabs were chosen for the roof on account of their lightness and heat-resisting properties. Skylights are provided in the boiler room in addition to windows.

At present four B. & W. marine-type, cross-drum boilers, having 12,322 sq.ft. of heating surface, are installed. They are designed for 300 lb. pressure and 200 deg. F. superheat and are steel-incased and insulated

by ½-in. asbestos mill board and 4-in. asbestos blocks. The drums and top circulating tubes are insulated with asbestos. Independent steel columns are used for supporting the boilers, which are not attached to the superstructure steel in any way.

The marine type of boiler was primarily designed for maximum steam capacity in small space, with high rate of evaporation and high pressures. A longitudinal-type boiler of this capacity would require six drums, with corresponding multiplicity of joints and connections, greater headroom and higher cost.

Each boiler is served by a fourteen-retort Westinghouse stoker driven through gears by a steam turbine mounted on the boiler-room floor. Air to support combustion of the fuel is supplied by four turbine-driven conoidal fans each capable of delivering 50,000 cu.ft. of free air against 6½ in. static of water pressure. If found necessary, it is relatively simple to connect the windboxes of adjacent furnaces so that one fan can supply air to two units instead of one. The products of combustion are delivered through a steel-plate breeching (asbestos-covered) to a radial-brick stack with top 225 ft. above the grates.

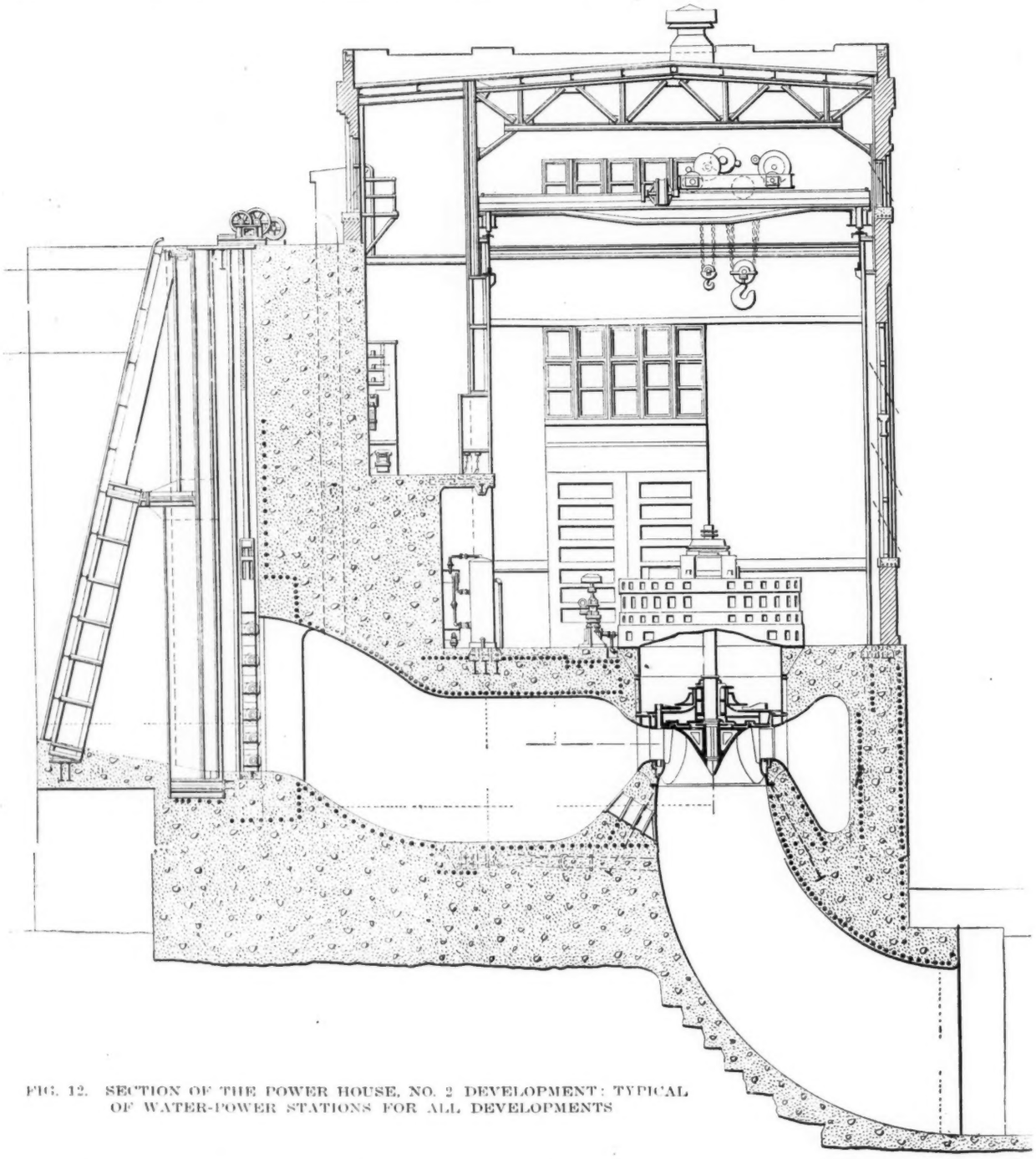


FIG. 12. SECTION OF THE POWER HOUSE, NO. 2 DEVELOPMENT; TYPICAL OF WATER-POWER STATIONS FOR ALL DEVELOPMENTS

The ashes are dumped into a firebrick-lined concrete pit under each boiler and by means of 1-cu.yd. metal cars and an electric hoist and telpher at the end of the building are taken to the yard and utilized at present for filling in the low places around the property. Later, the ashes will be deposited in a hopper and taken away by cars.

A water-clarifying plant having a capacity of 4000 gal. of water per hour is used for treating boiler-feed water, which carries considerable matter in suspension during flood season. From the clarifying plant the treated water is taken by gravity to a clear-water well, and thence pumped into a feed-water heater which also receives the exhaust steam from all the auxiliaries. Since the plant is run at full load, practically all the time steam drive was used almost exclusively for auxiliary drive as the exhaust steam is fully utilized.

Condensing water is obtained from the New River, which, while furnishing an adequate supply, carries an unusual amount of débris at certain times of the year. As a result extra efforts have to be taken to prevent clogging of the condensers. To facilitate clearing away débris that collects in front of the intake mouth dupicate screens and hoists are provided so one may be cleaned while water is passing through the other. Stop logs may be inserted in grooves of the tower for cleaning tunnels when necessary.

As the plant is interconnected in a system with several sources of power, one turbo-generator was installed instead of two or more units of smaller capacity.

The switching apparatus and electrical equipment is

IMPORTANT DATA OF GLEN LYN STEAM STATION, APPALACHIAN POWER CO.

Location, Glen Lyn, Va., on New River, with spur track connections from N. & W. and Virginian R.R.

Station, main generating capacity, nominal kw. (present unit), 20,000; 60,000 kw. future.

BOILER ROOM

Width of firing aisle	25 ft. 1 in.
Type of boiler, B. & W. sectional cross-drum	Water-tube
Number of boilers (present unit)	4
Horsepower each boiler	1,232

Tubes: 42 header sections, 14 tubes, each 4-in. diam., 18 ft. 0 in. long
Steam drums: One 60 in. x 29 ft., 10 in. long
Six 4½-in. consolidated safety valves
Two 4-in. feed-water inlets
Four 2½-in. blowoff outlets
Two 6-in. steam outlets

Grate surface, sq.ft. (active)	246
Heating surface, sq.ft. (each boiler)	12,320
Heating surface per sq.ft. active grate areas, sq.ft	50.1
Heating surface per installed kilowatt normal capacity of generators	2.46
Working pressure, lb. per sq.in	300
Superheat, deg. F	250

BOILER PERFORMANCE

Boiler Horsepower	Boiler Rating, Per Cent.	Combined Efficiency, Per Cent.
1232	100	77.5
1850	150	76.0
2470	200	73.0
2810	228	70.0
3080	250	67.0
3700	300	60.0

Three-hr., 2-in. draft at damper temp., 650 deg. F. at damper

Stoker, Westinghouse underfeed (14 retorts to each boiler)
Grate surface (active) ..... 246 sq.ft.
Coal: Pocahontas, fixed carbon, 71 per cent volatile, 19 per cent moisture, 2 per cent. ash, 8 per cent. sulphur, 1.5 per cent. heating value (dry); 14,000 B.t.u.; as fired, 13,720 B.t.u.

BOILER AND FURNACE EFFICIENCY

Combined Boiler and Furnace Efficiency, Per Cent.	Per Cent. Boiler Rating
77	150
76	200
75	250

CAPACITY

Per Cent. Boiler Rating	Duration
300	24 hr.

PERFORMANCE DATA (ONE BOILER)

Boiler Rating, Per Cent.	Air per Min., 65 Deg. F. Cu.Ft.	Lb.	Windbox Pressure, In. Water
150	19,000	1,440	2.5
200	25,500	1,930	3.2
250	34,000	2,570	4.3
300	44,000	3,330	5.5
...	50,000	3,780	...

FAN CHARACTERISTICS

Cu.Ft. Air per Min.	Velocity Pressure, In.	4 In. Static, R.P.M.	Pressure, Hp.	5 In. Static, R.P.M.	Pressure, Hp.	6 In. Static, R.P.M.	Pressure, Hp.	7 In. Static, R.P.M.	Pressure, Hp.
29,550	0.202	843	33.6	925	43.0	1002	52.9	1075	63.3
36,090	0.302	875	40.5	956	50.7	1030	61.5	1101	72.8
42,650	0.422	909	48.8	989	60.0	1064	71.7	1131	83.9
49,210	0.560	953	58.7	1027	70.9	1099	83.5	1163	96.8

Stoker Drive: Connected by reduction gear and Morse chain to Westinghouse noncondensing turbine
Fan Equipment: No. 7½ D.W. turbo type conoidal fan connected through a flexible coupling and reduction gear to a Westinghouse noncondensing turbine
Capacity furnace ash hopper, each, cu.yd 33
Capacity ash, cars, each, cu.yd 1
Soot blowers, "Diamond," 12 units on each boiler

Main steam valves, "Crane" cast-steel body with monel metal seats and stems
Automatic stop-check valves, "Crane" vertical
Blowoff valves, "Everlasting"
Feedwater heater, one "Cochrane" horizontal cylindrical, capacity 250,000 lb. per hr.
Feed-water pumps (two), Lea & Courtenay
Type, 4 in., four-stage single-suction uniflow
Capacity, 500 gal. per min. against 350-lb. pressure, or a total head of 810 ft. direct-connected to a two-stage noncondensing type L. G. E. turbine
Water clarifying: Booth, type F-T, electric-motor driven, purifying capacity, 4,000 gal. hourly; softener tank, 16 ft. 3 in. diam. by 16 ft. 0 in.; filter tank, 6 ft. 0 in. diam. by 6 ft. 4 in.
Chimney: One (present unit) 200 ft. x 16 ft. diam. at top; top 225 ft. above grates
Turbine (present unit) General Electric, 60 cycle, three-phase, 13,200-volt, 1800 r.p.m., 15,000 kw. @ 80 per cent. load factor; excitation, 100 kw. @ 125 volts, 40,000 cu.ft. air per min.
Dimensions, including direct-connected exciter: Length 42 ft. 6 in., width 19 ft. 8 in., height 11 ft. 9 in., weight (net) 385,000 lb.
Capacity per sq.ft. floor space covered by turbine (rated) ..... 18.1 kw.
Weight of turbine, lb. per rated kw 25.66
Steam consumption per kw.-hr.: pressure, 250 lb.; superheat, 200 deg. F.; back pressure 1 lb. abs.; bar. at 1500 ft. = 28.75 in.

Kilowatt Output of Generators	Pounds per Kw.-hr.
7,500	11.45
11,250	10.75
14,000	10.45
15,000	10.50
18,750	10.80

Exciter: Direct connected to horizontal turbo-generator; Type M.P.C., poles 6, kw. 100; speed 1800 r.p.m., volts 125, field winding, shunt; amperes, 800
Ventilation: One Spray Co. air washer and cooler, capacity, 40,000 cu.ft. per min. motor, 440 volts, three phase, 60 cycles, 1800 r.p.m., 7.5 hp.; pump, 231 gal. against 70-ft. head
Condenser (present unit): Wheeler Condenser and Engineering Co.

Steam to be condensed per hour, lb	220,000
Condensing surface, sq.ft	30,000
Diameter of tubes, in. O.D	1
Length of tubes	20 ft. 0 in.
Gage of tubes, B.w.g	18
Circulating water, gal. per min	30,000
Circulating pump power, b.h.p	210
Circulating pump speed, r.p.m	280
Circulating pump turbine speed, r.p.m	2,800
Circulating pump turbine steam, lb. per hr	5,750
Circulating pump section, diam., in	30
Circulating pump delivery, diam., in	30
Circulating pump steam, diam., in	3
Circulating pump exhaust	6
Air pump speed, r.p.m	2,000
Air pump capacity of free air per min., cu.ft	45
Hotwell, in	5
Hotwell speed, r.p.m	2,000
Air and hotwell pump, turbine b.h.p	135
Air and hotwell pump steam per hour, lb	4,500

Steam power 250-lb. gage, 200 deg. superheat, 2 lb. back pressure
Condenser performance: At 30 in. barometer (28.75 in. at Glen Lyn)

Pounds Steam per Hour	Temperature Circulating Water, Deg. F.	Vacuum, In. (30 In. Barometer)	Vacuum at Glen Lyn, In.
206,750 = 18,750 kw. @ 11.00 lb.	60	28.83	27.58
212,000	70	28.35	27.10
220,000	11.74	80	27.75	26.50
275,000	14.65	80	27.00	25.75

Transformers: Three single-phase, water-cooled, 60-cycle, 6250-kv.-a. outdoor-type transformers 88,000/13,000 volts, 11,800/12,400/13,650 volts taps
Efficiencies: Full load, 98.7; ¾ load, 98.7; ½ load, 98.5
Weight Transformers: 29,300 lb., oil, 12,200 lb.; total, 41,500 lb.
Dimensions: Height over bushings, 17 ft. 11½ in.; over cover, 13 ft. 6½ in.; length, 7 ft. 11½ in.; width, 4 ft. 8½ in.
Water required at full load, 23 gal. per min. per transformer at 25-lb. pressure
Switchboard equipment:
One T.P.S.T. H-6 1200 amp. 15,000 V. tandem bottom connection oil-circuit breaker
Two T.P.S.T. K-22 150 amp. 110,000 V. outdoor type oil-circuit breaker
Four 150 amp. bushing-type current transformers and two operating solenoids
Six S.P.S.T. 90,000-volt 300-amp. outdoor-type disconnecting switches
Three S.P.S.T. 15,000-volt, 1200-amp. L.G.-16 indoor-type disconnecting switches with
Three three-phase solenoid control relays
Two three-phase, 90,000-volt outdoor-type aluminum-cell lighting arresters
Six 90,000-volt, 300-amp. choke coils, control circuits, 125 volt from storage batteries
Oil-filtering System: No. 6 Peterson, capacity 400 to 600 gal. per hr.; pump, 1-in. Taber rotary, motor-driven, ½ hp., 440-volt, three-phase, 60-cycle, 1,200 r.p.m.; overflow gage

simple, although it will be more elaborate in the future, after more units are added. The 13,200-volt generator leads run direct through a 15,000-volt 1200-amp. H-6 automatic motor-operated oil circuit-breaker to the main transformers, which are installed outdoors and rated at 6000 kv.-a., 13,200/80,000 volts each. Taps from these leads are taken through a disconnecting switch and a 15,000 volt, 300-amp., K-2 automatic hand-operated oil-circuit breaker to a bank of 100-kv.-a. 13,200/440-volt outdoor-type transformers which supply energy for station motors. Another set of transformers supply energy for station lights. The high-tension circuits run from the main transformers through a 110,000-volt, 150-amp., K-22 nonautomatic solenoid-operated oil circuit-breaker, also installed outdoor. Lightning arresters, choke coils, etc., are employed as usual. The arrangement of switches mentioned and illustrated makes it possible to feed back from the line in case the generating unit is shut down and also to furnish power for the auxiliaries at times when power is shut off the transmission line. Owing to the fact that there is but one unit, no low tension bus is needed, but space has been provided for concrete cells, which will be built when the station is extended. The outside switching arrangements are temporary, being intended for the present installation only. When the extension is added provision will be made for other outgoing lines, when a steel structure will be built. No reactors have been provided for this installation as it was thought that the length of line would cushion any disturbances that might occur. However, they will be provided when the next unit is added.

A 30-mile electric transmission line connects this plant with the system at Switchback, W. Va. A telephone circuit is carried on the same poles.

The plants were designed and constructed by Vielé, Blackwell & Buck, 49 Wall St., New York, and the writer was in charge of the work at Glen Lyn and engineer on construction of the hydro-electric stations.

A Progressive Cotton-Mill Community

THE progress made by the South in the textile industry during the last decade is exemplified very satisfactorily by a group of cotton mills at LaGrange, Ga. A little more than ten years ago the Unity Cotton Mill was the only one of the present group in existence. A few years later the Elm City Mill was built; this was followed by the Unity Spinning Mills, and the latest addition to the group is the Hillside Mill, which was built in the latter part of 1915.

The power plants of this group of mills do not embody any radical features or startling innovations; they merely represent substantial, high-grade engineering as judged in the light of cotton-mill practice at the dates when the mills were built. The power-plant equipment of the Hillside Mill consists of seven horizontal return-tubular boilers, 78 in. by 20 ft. each, and an 1800-hp. cross-compound engine, which drives most of the mill through the conventional rope drive. The steam plant is supplemented by alternating-current motors in one or two departments, these motors being served from the transmission lines of the Columbus Power Co.

The power plant is somewhat unusual in the fact that no reciprocating pumps are used. The boiler-feed pump is a turbine-driven centrifugal. It takes water from the bottom of the hotwell, where it is comparatively still and less likely to be contaminated by oil, and delivers it to the boilers through a closed feed-water heater; the temperature of the water at the boiler inlet ranges from 200 to 205 deg. F.

The condensing equipment consists of a 30-in. barometric condenser and a turbine-driven centrifugal circulating pump. With supply water at 80 deg. F., this outfit maintains a 26-in. vacuum when the engine is developing 2400 hp. The water from the hotwell is cooled by means of spray nozzles.

The power-plant equipment of the Unity Spinning Mill consists of 800 hp. in horizontal return-tubular boilers, a cross-compound engine of 750 hp. and 250 hp. in electric motors taking current from the Columbus Power Co.'s transmission line. The condensing equipment is of the barometric type with a spray-nozzle system for cooling, as in the Hillside plant.

The power plant of the Elm City Mill comprises four horizontal return-tubular boilers of 250 hp. each and a cross-compound engine of 800 hp. The condensing system at this plant consists of a surface condenser and the usual pumps.

The Unity Cotton Mill equipment is of the ordinary type in vogue ten or twelve years ago.

The Hillside Mill equipment consists of 30,000 spindles, 700 looms and a corresponding outfit of pickers, carding machines, etc. The mill employs 1400 operatives and turns out 10,000,000 lb. of ducks and specialty fabrics per annum.

The Unity Spinning Mill contains 14,700 spindles and turns out 3,640,000 lb. of yarn annually for the knitting trade, fire-hose and automobile-tire trades.

The Elm City Mill contains 11,664 spindles and 138 looms; its annual output is 4,000,000 lb. of heavy duck.

The Unity Cotton Mill operates 11,000 spindles and 150 looms; the annual output is about 3,600,000 lb. of duck.

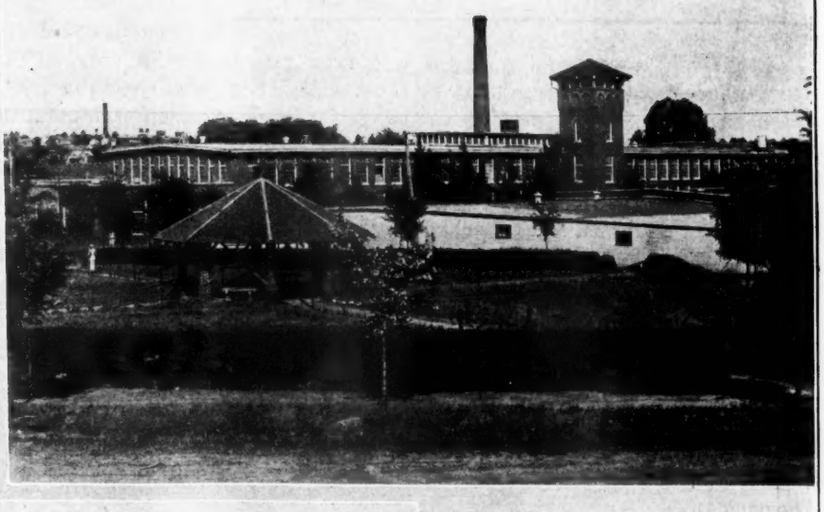
This group of mills is situated in a settlement known as Southwest LaGrange, just outside of LaGrange proper. This settlement has been developed according to the most modern ideas of scientific welfare work. At each of the mills there is a Martha Washington Inn, with clean, wholesome accommodations for the "unattached" female operatives and a Ben Franklin Inn for the men. A flourishing library and a Y. M. C. A. organization, a thoroughly up-to-date school system and several churches supply the moral, mental, spiritual and physical needs of the community. There is also a well-equipped hospital, and an agricultural department which includes a large greenhouse. A feature of the Y. M. C. A. that might profitably be emulated by other similar organizations is a systematic exercise period of thirty minutes before work hour in the morning. The men and boys gather on the athletic field and engage in ball-throwing, football kicking and other moderate stunts which tend to eliminate foggy brains and flabby muscles.

The founder of this community and the man whose ideas have directed all the features of its development is Fuller E. Calloway. Mr. Calloway has a positive genius for organization and an uncanny knack in the selection of executive lieutenants.

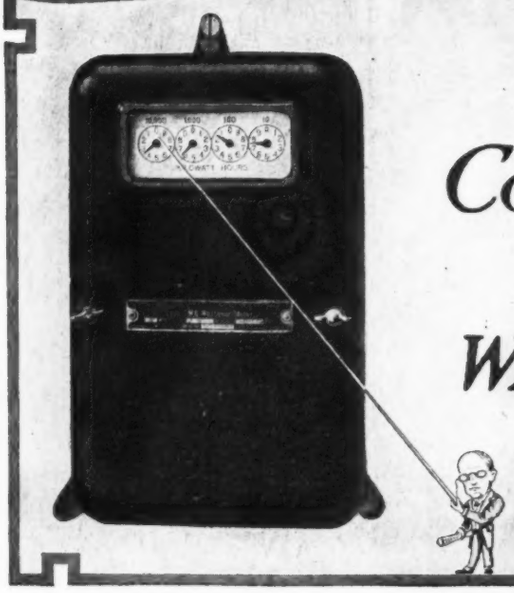
COTTON MILLS
at La Grange, Georgia.

Back View of Hillside Mill

Elm City Mills



Unity Spinning Mill



How to Correctly Read A WATT-HOUR METER

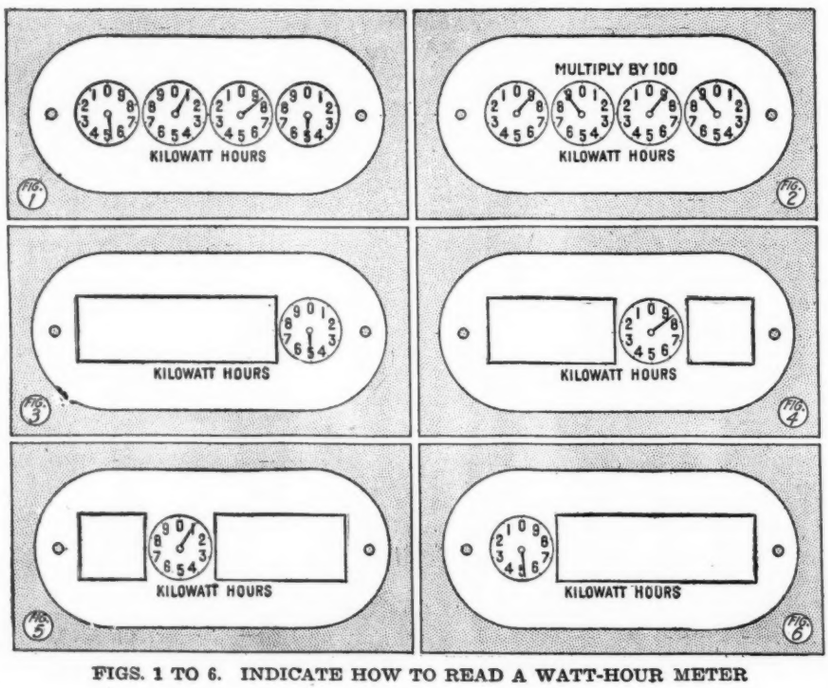
By

Victor H. Todd

Gives the different forms of dials used on various makes of watt-hour meters and explains how to read them. The chances for making an incorrect reading due to misplaced hands on the dials or failing to use a constant are pointed out.

IN VIEW of the essentiality of the watt-hour meter to produce accurate records, it is often called the cash register of the operating company, for it determines the revenue that the company should receive from the sale of electric power. For this reason it is, or should be, very accurate, and this accuracy is often maintained by elaborate and expensive tests and standards. Not only should the meter be accurate, but it must also be read correctly. If the error is in the consumer's favor, it means an actual loss of revenue to the company, and if in the company's favor, a loss to the consumer unless he checks the meter each time it is read. For this reason the consumer should learn to read the watt-hour meter, and check the meter reader every time a reading is taken. The reading of a watt-hour meter is often attended with the idea, by the inexperienced, that it is a difficult task and requires considerable experience, when in fact quite the reverse is the truth; therefore it is the purpose of this article to present the subject in such a way as to meet the need of those not familiar with the reading of a watt-hour meter.

The standard dial face for watt-hour meters adopted by the National Electric Light Association is similar to that shown in Figs. 1 and 2. Previous to this standardization each manufacturer had his own style of marking the dial. But outside of the actual variation in the arrangement, the number and marking of dials on watt-hour meters of various makes, the underlying principle is the same. The rotating element is carefully adjusted by various means so that it rotates at a definite speed, proportional to the power transmitted in the circuit which it is measuring. This element is geared to a train of gearwheels which moves the pointers, or hands, proportional to the product of the watts or kilowatts and the hours, which is called watt-hours or kilowatt-hours. One kilowatt-hour is equal to 1000 watt-hours. The dials are all arranged with a 10



FIGS. 1 TO 6. INDICATE HOW TO READ A WATT-HOUR METER

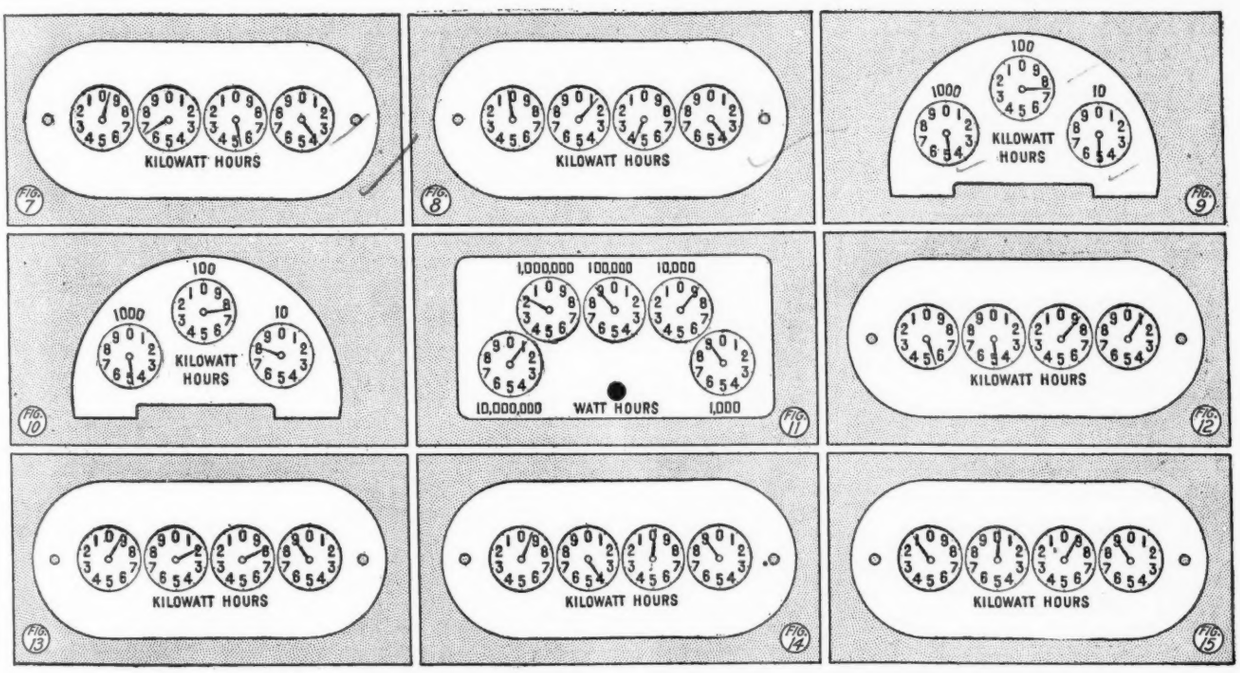
to 1 ratio; that is, any pointer or hand moves ten times as fast as the pointer of the dial to the left. In other words, it takes ten revolutions of the fastest-moving pointer at the extreme right to equal one revolution of the next pointer to the left. It takes ten revolutions of the second dial pointer from the right to make one revolution of the third dial pointer, and so on. Another way of expressing it, is to say that one revolution of the fastest moving pointer will equal one division, one-tenth of a revolution, on the next dial.

It will also be noticed from the figures that where one pointer rotates in a clockwise direction the next turns counterclockwise, and so on. The sequence of the numerals clearly shows in which direction the pointer is rotating.

The generally approved method of reading a watt-hour meter is from right to left; that is, read the fastest-moving dial first, then the next, etc., and set the figures down from right to left as noted from each dial. As a typical example, take the dial shown in Fig. 1. Hold a piece of paper over the three left-hand dials and consider only the extreme right-hand or fastest-moving pointer as shown in Fig. 3. It tells two things: First, that the last number in the reading is 5 unless there is a constant, as explained later, and second, that the next pointer, although it cannot be seen, must be halfway between two numbers, 0.5 of a division. Therefore the number 5 is jotted down, and the position of the pointer on the next dial mentally noted, then the second dial is inspected, as in Fig. 4. The pointer is found to be halfway between 8 and 9. Now it cannot be 9 because the pointer has not yet reached 9, so the lower figure (8) is jotted down, making the last two numbers 85.

This second dial also tells that the third pointer has almost reached a number, 0.8 of a division, although as yet the number is unknown. An inspection of Fig. 5 shows that the pointer has almost reached 1, but as the preceding dial says it has not yet reached 1, therefore the lower numeral (0) must be used, making the last three numbers 085. This also shows that the next unknown dial to the left, has just passed a numeral, which is found to be 5 by referring to Fig. 6, consequently 5 is set down, making the total reading 5085.

Now this does not mean that the consumer has used 5085 kilowatt-hours; it simply indicates that the meter has recorded that much since it started to run. To get the consumption of power or kilowatt-hours for a definite period, it is necessary to have the reading or indication at the beginning of the period and at the end. The difference between the two readings will indicate the actual amount of power used. These readings may be taken month after months and the reading at the end of one period may be taken as the reading at the beginning of the next.



FIGS. 7 TO 15. SHOWING SOME DIFFERENT STYLES OF WATT-HOUR METER DIALS

Fig. 7—Four-dial, reading 9654. Fig. 8—Four-dial, reading .0144. Fig. 9—Three-dial, reading 475. Fig. 10—Three-dial, reading 478. Fig. 11—Thompson, five-dial, reading 1,188,900 watt-hours, or 1188 kilowatt hours. Fig. 12—Misplaced hand on second dial; apparent reading 5481, correct reading 5491. Fig. 13—Misplaced hand on second dial; apparent reading 9189, correct reading 9179. Fig. 14—Misplaced hand on third dial; apparent reading 9499, correct reading 9399. Fig. 15—Misplaced hands on second and third dials; apparent reading 1099, correct reading 0989.

When the reading at the end of a period is less than at the beginning—that is, when the slowest-moving pointer has passed zero, as for instance in Figs. 7 and 8, where Fig. 7 gives the reading (9654) at the beginning of the period, and Fig. 8 gives the reading (0144) at the end of the period—the total consumption of power is obtained by placing the numeral 1 in front of the last reading and subtracting as in other cases. For instance, the reading, Fig. 8, at the end of the period would be 10,144 instead of 0144. Subtracting 9654, Fig. 7, from 10,144 gives the power used as 490 kilowatt-hours. After the reading is taken at the end of the next period, the reading 0144 is used. Multiplying 490 by the rate per kilowatt-hour gives the cost. In this case, if the rate is 10c. per kilowatt-hour, then

490 × $0.10 = $49. If the rate had been 6c. per kilowatt-hour, the bill would be 490 × $0.06 = $29.40

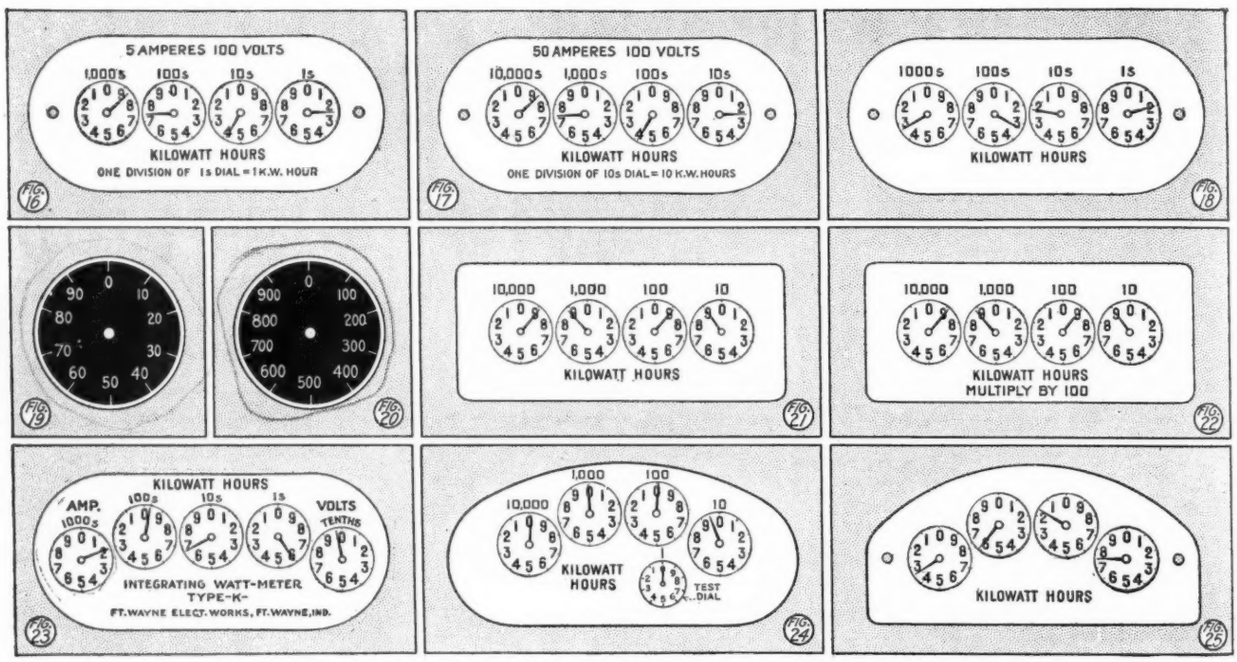
Some makes of meters have five dials and some only three. The five-dial meter is satisfactory, although one dial is entirely unnecessary. Five-dial meters generally read in watt-hours instead of kilowatt-hours and the fastest dial is generally disregarded. The three-dial meters should not be used, as there are numerous cases where the slowest dial makes more than one complete revolution in a period. An example of this is shown in Figs. 9 and 10. The reading at the beginning of the period was 475, and at the end of the period was 478. Apparently, the consumer had used only 3 kilowatt-hours, and was billed accordingly. But the fact was, that the last dial had been completely around, and 3 kilowatt-hours more, so the actual amount was 1003 kilowatt-hours instead of only 3.

In reading the five-dial meter, Fig. 11, the first right-hand dial may be neglected since one revolution of its pointer indicates only 1000 watt-hours, or 1 kilowatt-hour, which can be read directly from the second dial from the right. A complete revolution of the second dial indicates 10,000 watt-hours, the third 100,000 watt-hours, the fourth 1,000,000 watt-hours, and the fifth 10,000,000 watt-hours. Dividing each of the values by 1000 gives 10, 100, 1000 and 10,000 kilowatt-hours respectively. This is the same as the standard four-dial meter in Figs. 1 and 2, therefore may be read the same as explained in Figs. 3 to 6. The second pointer from the right, Fig. 11, will be read 8 and not 9, since the pointer on the first dial has only reached 9 and will have to be on 0 or pass it before the second dial will be reading 9. The third-dial pointer also reads 8 for the reason that the second-dial pointer has not reached 0 but is slightly back of the 9. Hence the reading of the second and third dials is 88. The fourth pointer indicates 1 and not 2, since the pointer on the third dial has not reached zero yet. This gives 188 as the reading of the second, third and fourth dials. On the fifth dial the pointer is slightly past 1, thus the meter reads 1188 kilowatt-hours. If the reading of the first dial is taken it is 900 watts, or 0.9 of a kilowatt-hour. Adding this to the reading of the other four dials gives 1188.9. But as before stated, the reading of the first dial is usually neglected and the reading is in this case taken as 1188 kilowatt-hours.

Reading a watt-hour meter would thus be very simple were the hands or pointers always correctly placed; but owing to careless placing, loose hands and excessive lost motion between gears, a pointer may have passed a number before it actually should or be behind a number when it should be ahead of it. For this reason, the dial to the right must always be consulted first. Look at Fig. 12. A quick, careless reader would say immediately 5481, taking as usual the lowest numbers. But the first dial on the right by pointing to 1 clearly indicates that the next pointer has passed a number, and as the second pointer says it is not quite 9, it is very evident that the hand is misplaced and is slightly back of its true position and should be a little in front of 9. So the correct reading would be 5491, a difference of 10 kilowatts.

As another example, take the dial shown in Fig. 13. A quick reading would be 9189, but a careful inspection will show that the first dial on the right, by indicating 9, clearly shows that the hand on the next dial has not quite reached a number, and as the next hand has actually passed the number, it is evidently misplaced and the true reading is 9179.

In Fig. 14, unless care is taken, the reading would appear to be 9499. But on examining the second dial it is seen that the pointer has not reached zero, where



FIGS. 16 TO 25. SHOW SOME MORE DIFFERENT STYLES OF WATT-HOUR METER DIALS

Fig. 16—Westinghouse, type C, 4 dial; reading 8742. Fig. 17—Westinghouse, type C, 4 dial; reading 87,420. Fig. 18—Fort Wayne, 4 dial; reading 3322. Figs. 19 and 20—Slickers to indicate constants to be used. Fig. 21—General Electric, 4 dial; reading 8889. Fig. 22—General Electric, 4 dial; reading 888,900. Fig. 23—Fort Wayne, 5 dial; reading 1965.9. Fig. 24—Sangamo, 4 dial; reading 9999. Fig. 25—Fort Wayne, 4 dial; reading 3617.

it would have to be for the pointer on the third dial to be on 4. But in this case the pointer has passed 4 when it should be slightly back of it, hence the pointer on the third dial is misplaced ahead of its true position and the correct reading is 9399, a difference of 100 kilowatt-hours.

On the dials Fig. 15 the reading of the hands appears to be 1099, but a careful inspection will show that the pointers on the second and third dials are misplaced. The pointer on the second dial apparently indicated 9, but on looking at the first dial it is seen that this pointer has not reached or passed 0, hence the pointer on the second dial is misplaced ahead and its correct position is slightly back of 9, so this dial's reading is 8 and not 9. On the third dial the pointer has passed zero, but this cannot be true because the pointer on the second dial has not completed its revolution, but, as pointed out in the foregoing, should be slightly back of 9, therefore the pointer on the third dial is ahead of 0 when it should be behind it. Then, since the pointer on the third dial has not reached 0, the pointer on the fourth dial cannot be exactly on 1, and the reading is not 1099 but 0989.

By far the greatest number of mistakes and costliest errors are made, however, by not using a constant or multiplying number when it should be used. When a large amount of power is being measured, it is impracticable to run the hands fast enough to indicate kilowatt-hours direct, so the gear trains are arranged to read 0.1, 0.01 or 0.001 of the correct amount, consequently the reading must be multiplied by 10, 100 or 1000 to get the true power consumed. In the standardized meters this number is marked on the dial as shown in Fig. 2, where a note says, "MULTIPLY BY 100." Therefore the reading, instead of being 8889, must be multiplied by 100, making the correct reading 888,900 kilowatt-hours.

The dial Fig. 17 very plainly states the value of one division on the first dial, where a note says, "ONE DIVISION OF 10S DIAL = 10 KW.-HOURS." In other words, if the pointer on the 10S dial moves from 1 to 2, it shows that 10 kilowatt-hours have been used, therefore every time the figure indicated by the last dial is set down, it must be followed by a cipher, so the reading on Fig. 17 would be 87,420 and not 8742, which is the correct reading in Fig. 16.

Other makers simply mark the dial 1S, 10S, 100S, etc., and leave off the note, but this simply means that 1 division from 1 to 2, or from 2 to 3, or from 5 to 6, etc., is the value by the letter "S." For instance, in Fig. 18 the reading is 3322 kilowatt-hours, but in Fig. 17 the first dial is marked 10S, meaning that each division is 10 kilowatt-hours and the reading is 87,420.

Others simply have the dials marked 10, 100, 1000, etc., in which case the number is the value of one complete revolution and not one division. Some central-station companies, realizing the great danger of misused constants due to lack of uniformity, use a little red sticker, similar to that in Fig. 19, and on any meter which is marked multiply by 10 or has the last dial marked "10S" they paste this little sticker on the dial. If it is marked "Multiply by 100" or "100S," the sticker shown in Fig. 20 is used. Its vivid color forcibly calls attention to the fact that the last number is more than 1 or 2 or 3, etc.

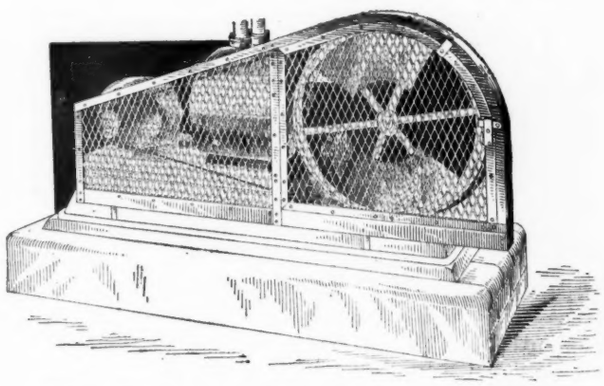
Another important point to watch is whether the dial is marked in watt-hours or kilowatt-hours. Figs. 11 and 21 show this. Fig. 21 reads in kilowatt-hours, but Fig. 11 reads watt-hours. Fig. 22 is the same style dial as in Fig. 21, but in the former a constant of 100 is used, therefore where the reading Fig. 21, is 8889 kilowatt-hours, in Fig. 22 it is 888,900.

If a meter has a dial like Fig. 23, the last dial is generally disregarded, the hand removed and a black sticker pasted over the figures. The test dial shown in Fig. 24 is also disregarded in computing the kilowatt-hours; it is for the tester's convenience only. Fig. 25 gives another arrangement of dials that read kilowatts. The dials are similar to those shown in most of the other figures, but are arranged around in a curve.

Thus it will be seen that there is a great liability to error through wrong reading or unused constants, and it is manifestly absurd to attempt to increase the revenue of a central-station company or keep accurate records of power consumption in different departments of an industry by maintaining a high meter accuracy, and then allow all kinds of errors in wrong readings.

"Steelcrete" Machine Guards

In many states the law demands that gearing, pulleys and various moving machinery shall be guarded in a suitable manner. Various methods are employed, such as railings, wire screens, guards, etc. A filling material for machine guards, known as "Steelcrete Mesh," is manufactured by the Expanded Metal Engineering Co., 8 West 40th St., New York City.



"STEELCRETE" GUARD AS APPLIED TO A MACHINE

Steelcrete mesh is cut from sheet plate steel and is pulled into a fabric of diamond-shaped meshes, the diamonds being joined at their "bridges" by short sections of the unsheared plate. This material is so tough that openings may be cut to any shape without weakening the guard and there is no danger of the strands separating. It also is capable of withstanding hard usage, and although a blow may dent it or even fracture one or more strands, the damage will not spread. Neither does it loosen up and sag nor disintegrate if a strand is broken.

No special tools are required to fit the guard in place, as the flat sheets are easily cut to fit the angle of the iron frame to which the mesh is attached with either rivets, bolts or spot-welding. The mesh is made in several sizes of diamonds and of various weights of material.

Operation at HOLTWOOD

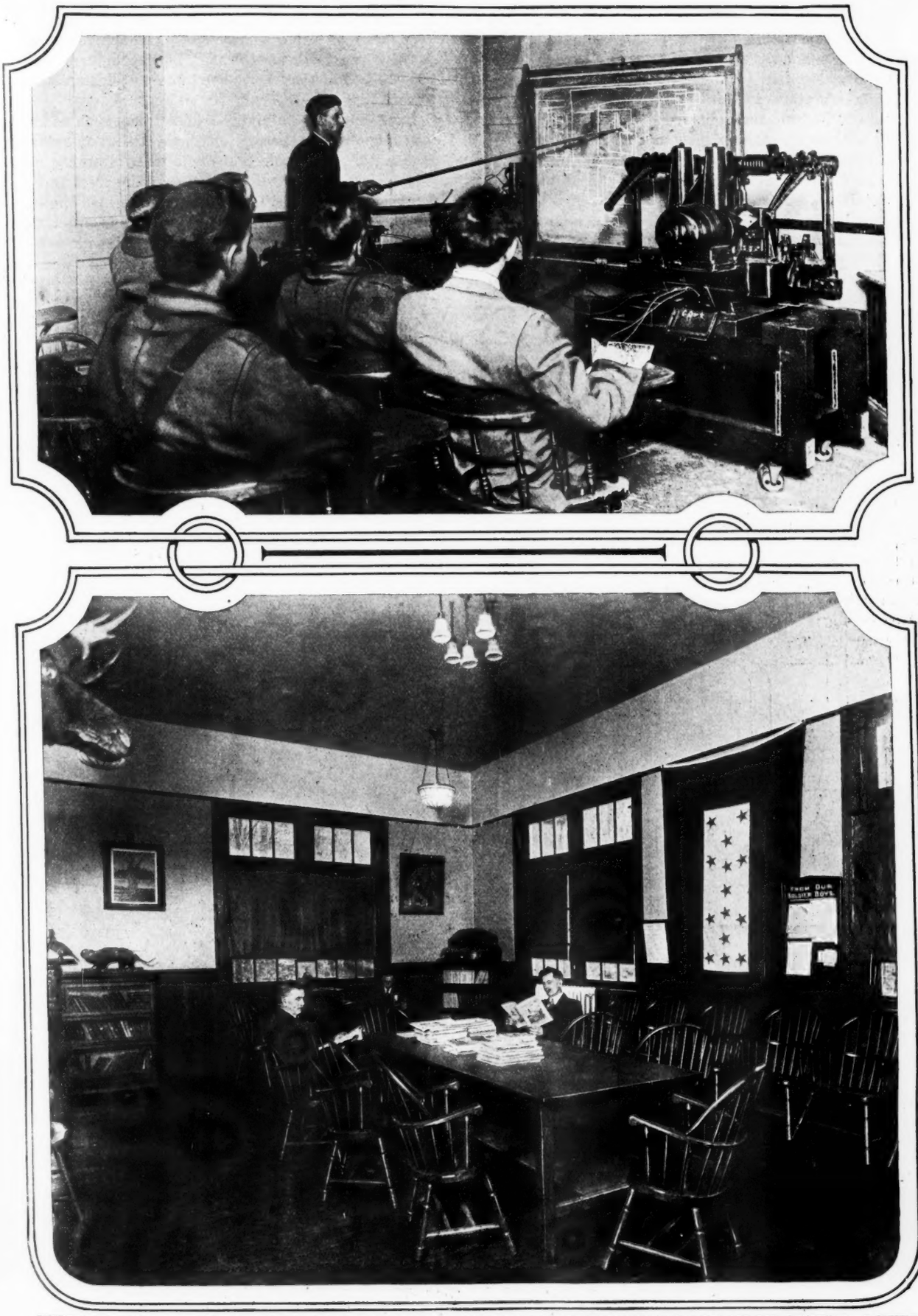
by Charles H. Bradley

Instructing the Power House Crew

HOLTWOOD is on the Susquehanna River about fifteen miles from Lancaster, Penn., and about forty miles in an air line from Baltimore. This station was described by the writer in *Power* for May 13, 1913, at the time of its completion. The power house and dam are of concrete construction, the dam being approximately 2370 ft. long and 53 ft. high with a base width of 65 ft. At present the station has a hydraulic capacity of 118,500 hp. in eight units with generators rated at 83,500 kw. All but unit No. 8 have double draft tubes. The station originally was laid out for 10 turbines of 13,500 hp. capacity each with generators of 7500 kw. continuous rating, and five waterwheels of such capacity were installed, but at that time the owners found that units of 17,000 hp. could be installed without alteration of the pits, and when pits Nos. 6, 7 and 8 were to be used turbines of 17,000 hp. were ordered. The last unit installed, that is No. 8, has a single draft tube. The generators send their current to the transformers at 11,000 volts, at which point it is stepped up to 70,000 volts for transmission to Baltimore and to Lancaster. The Susquehanna is a widely fluctuating river. In times of high water there may be a flow of 400,000 cu.ft.-sec., and during low water the flow may drop as low as 400 cu.ft.-sec. There is no seasonal storage available. Fig. 5 shows an interior view of the turbine room. All important instructions to the crews are in writing and from the office of the chief operator. The orders are numbered and the sheets bound. Two volumes of instructions are in current use; namely, permanent instructions and current instructions.

This is the first of several articles that treat of operation and methods in the large hydroelectric station of the Pennsylvania Water and Power Co. at Holtwood, Penn., on the Susquehanna River. This article deals with the methods used in the instruction of the crew.

Permanent Instructions—These are in the nature of general rules to guide the crew. Several copies are issued, the floorman having one in his desk on the turbine-room floor; the switchboard operator also has one. A copy is kept in the office of the chief operator. When an employee has read and understands the rules and instructions he signifies to this effect by signing his name and the date on the last sheets of any particular set of instructions. This applies also to current instructions. At periodical intervals instructions of a permanent character are taken from current instructions and bound in the permanent instructions book. Bulletins or current instructions when superseding conflicting orders in the permanent instruction book, make specific references to such orders. In addition to the two sets of instructions a bulle-



UPPER PICTURE: CLASS OF OPERATIVES RECEIVING INSTRUCTIONS IN OPERATION OF AN OIL SWITCH. LOWER PICTURE: THE LIBRARY AT THE CLUB FOR THE POWER-HOUSE CREW AT HOLTWOOD

tin board is provided. Ignorance of the rules and instructions is not accepted as an excuse for noncompliance. When instructions are not understood, the person to whom they are not clear inquiries of his superior for interpretation. All employees are periodically examined as to their knowledge of the permanent instructions concerning their work. The book of permanent instructions is made up of chapters on the following: General Station Rules, Safety Rules, Normal Electrical Operation, Abnormal Electrical Operation, Normal Hydraulic Operation, Abnormal Hydraulic Operation, Holtwood Records and Forms, Duties (this last chapter is devoted to the duties of each employee), Holtwood Hydraulic Maintenance and Electrical Maintenance. A sectional view of the station is shown in Fig. 3.

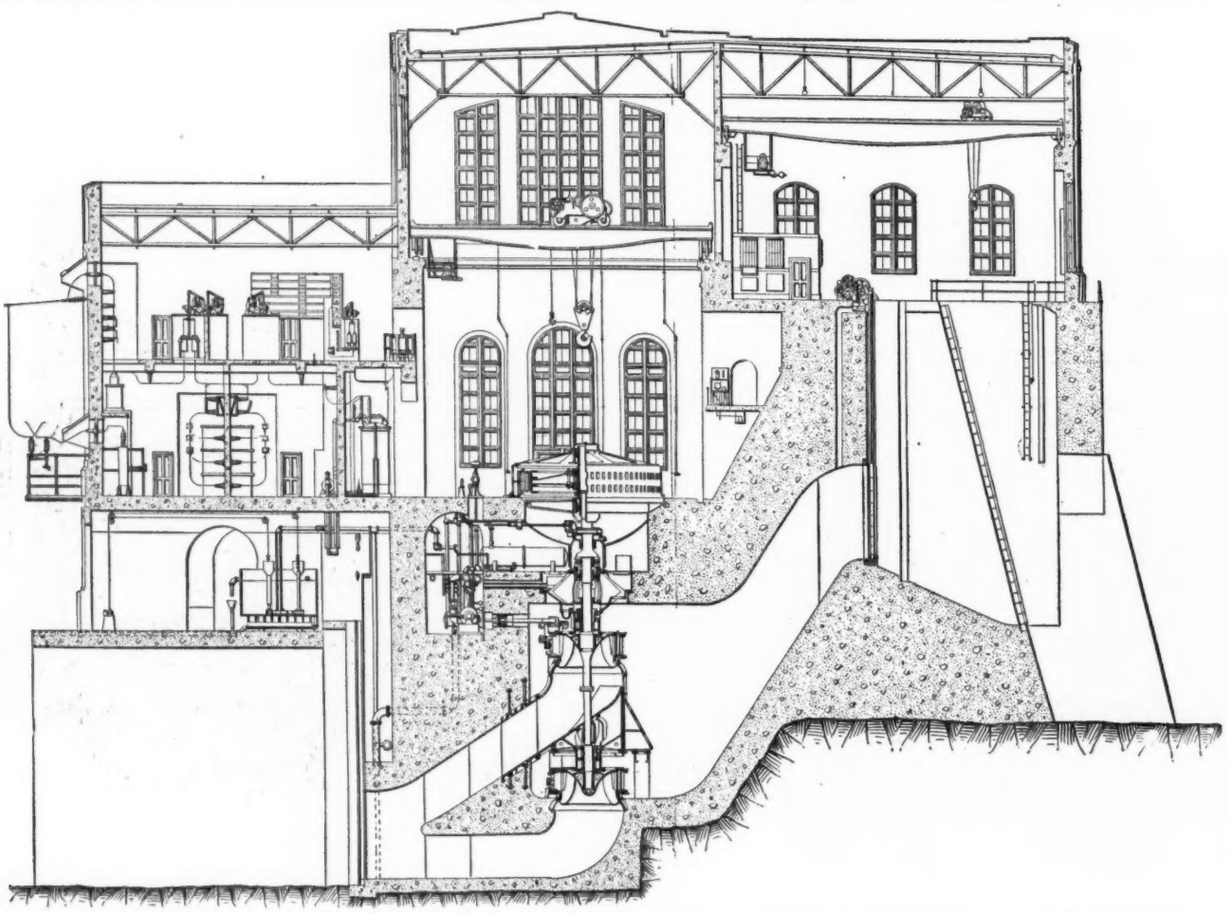


FIG. 3. SECTIONAL VIEW OF THE PENNSYLVANIA WATER AND POWER CO.'S STATION AT HOLTWOOD, PENN.

Working hand in hand with these instructions is the promotion system, according to which promotions are given on merit and not on seniority.

The company has provided a library in the clubhouse near the plant, and a large assembly hall, used for moving pictures, theatrical and social entertainments and also for lectures by outside speakers. A room in the station is fitted for lectures by heads of departments. Wide-arm chairs on which to lay note paper are used by those attending the lectures. Whenever possible, lectures are given with the actual apparatus discussed on view in the turbine room when such apparatus is conveniently portable. See Figs. 1, 2 and 4.

Serious troubles are reported in full, and when a discussion of these troubles, their causes and means of prevention is of value to the crew, the analysis and discussions are made by the man most competent and the reports bound and made available to all employees interested.

Excepting for the highly trained men, such as switchboard operators, testing engineer, chief operator and assistants, a hydroelectric plant when starting up depends upon the natives of the towns nearest the plant for help; that is, for cleaners, governormen, pumpmen floormen, machinemen, etc. A green man entering the employ of the company at Holtwood is started as a cleaner. As he progresses he is promoted in the following order: Cleaner, extra governorman, second pumpman, governorman, floorman, machineman, assistant operator and operator.

When the green man begins, he is given a sheet which tells him what are his duties. He is encouraged to learn as much as possible about the work of the rank next highest to his own, to which he will be promoted if fit. The assistant chief operator uses a loose-leaf book knows as "Progressive Standards of Advancement." In this he has a number of questions relative to the duties and mechanism in care of the various grades of men just mentioned. Periodically, he questions the men on the operation, care and maintenance of equipment in their charge and that in charge of the men in the next progressive position. This examination not only keeps the men studious and attentive to their work, but enables the management to soon discover the deadwood,

and to be just in promotion, which, as stated, is solely on merit. The examination is an excellent check upon the operation in general. It reveals if the foreman or superior in charge of the man examined has instructed him as he is supposed to do; it shows that perhaps circumstances of load and shifts have given the man no opportunity to perform work which he should know how to do. For example, a governorman in the earlier part of his career may not have had occasion to cut in or out a turbine for several weeks owing to the load conditions during his watch. In such cases arrangements are made to have him do this in a day or two from the time that it is known that he has not had opportunity to do this work for some time.

The most sought-for opportunities for gaining practical experience of value are those when the station is operating under abnormal conditions, such as lightning, frazil ice run, etc. This is the time when the previously acquired knowledge is put to the real test for proper observation, correct diagnosis and quick action. Men off shift are permitted to come to the station at such times, either actually assisting under the orders of the operator in charge, or merely as observing witnesses, for their own benefit. In either case, they are paid their regular wages while volunteering outside of their regular shift hours.

"Progressive Standards of Advancement" is in many respects a unique bit of literature and practice. It forms primarily a basis of study for all operating employees, covering practically every important description and operating feature. The questions are divided into sections: First, General Station Knowledge and Theory; second, Demonstrations; third, Specific Questions. These last cover comments on disturbances to regulations, interruptions and tests of station apparatus. The first section applies only to foremen, machinemen, assistant operators and operators.

The comments on disturbances and interruptions cover such subjects as Frazil Ice, Assistant Operator's Mistakes at Highlandtown Substation, Lightning-field Relay Trouble, Foremen's Mistakes, Sleet Trouble on Baltimore System, Cable Failure Followed by Trouble between Stations, Voltage Disturbance Caused by Failure of Pipe Fitting in Governor Pressure System, Efficiency Tests of Turbines. The foregoing are typical of the literature available to the men. Each report or comment analyzes the cause of the trouble, tells what should have been done, what mistakes were made and the probable causes why they were made.

There follow a few typical questions in the examination of some of the men in the various positions; the questions are from *Progressive Standards of Advancement:*

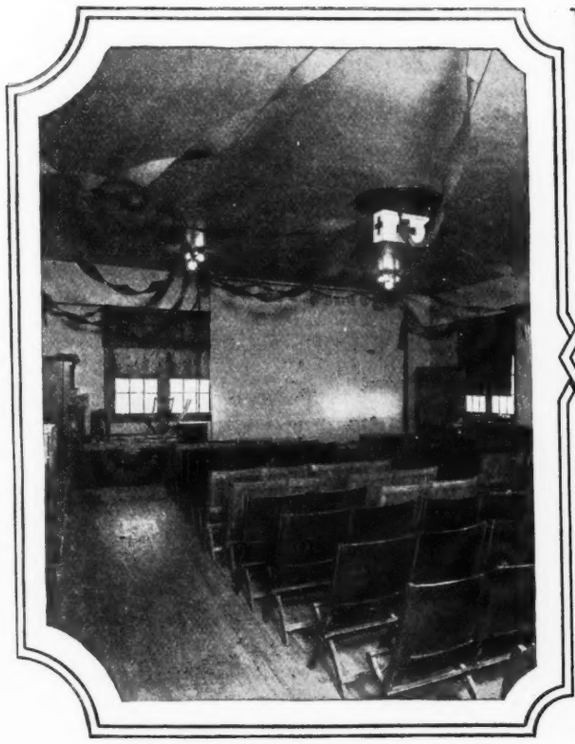


FIG. 4. LECTURE ROOM AT THE CLUB

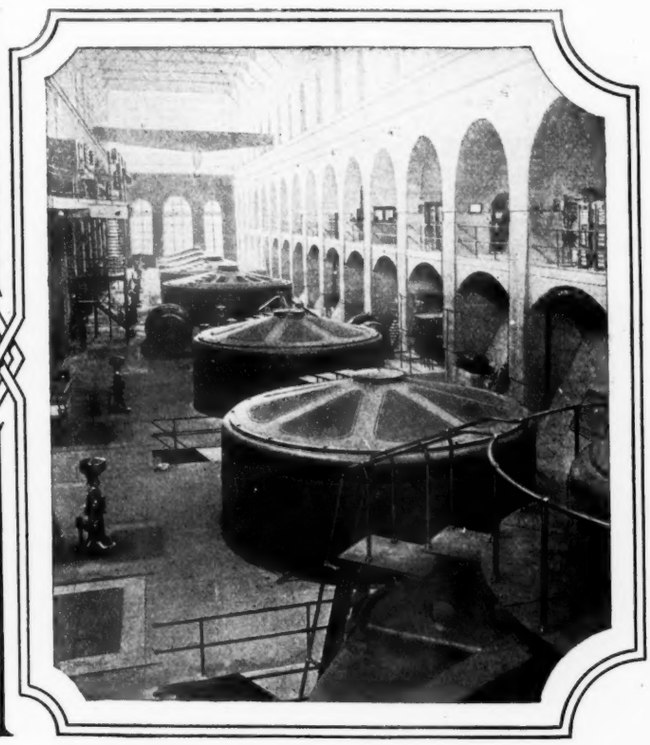


FIG. 5. INTERIOR VIEW OF TURBINE ROOM

Generator Cleaner—Demonstrate the starting of No. 3 air compressor.

Demonstrate the starting and stopping of a unit on hand control.

Enumerate the duties of extra governorman (this is the position to which the cleaner will be promoted).

How many pumps are there on the governor-control system?

Demonstrate sawing a piece of metal with a hacksaw.

Demonstrate cutting serviceable threads on a ¾-in. pipe.

Extra Governorman—What is the color scheme for the piping in the station?

What is the code used in whistle signaling?

Demonstrate reading an oil-meter dial.

Demonstrate changing a unit from hand control to governor control and vice versa.

Demonstrate cleaning screens in the water-supply line to No. 8 turbine.

Explain the safety rules relating to the hydraulic section of the station.

Demonstrate the operation of the headgate winches.

Pumpman—What is the oil flow in gallons to all bearings on turbines and generators?

Sketch on the blackboard the central pumping system, governor and hand-control connections.

What precautions are to be observed in the pump tunnel in case of ice trouble?

Sketch on the blockboard the lubricating oiling system.

Why is the governor-control system divided into two distinct sections?

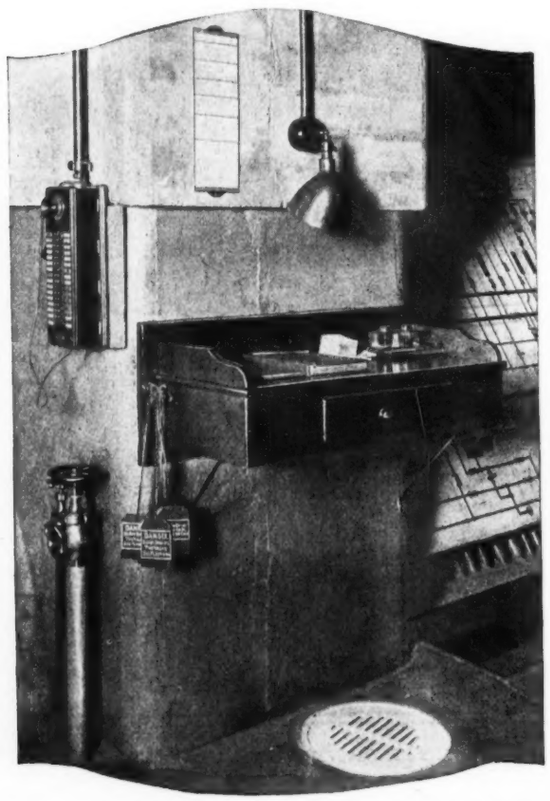


FIG. 6. FLOORMAN'S DESK ON TURBINE-ROOM FLOOR

Explain what you would do after a section of piping on the governor control system had failed due to the bursting of a fitting or the blowout of a gasket.

In the event of serious station trouble, which section of the station must first have concentrated attention to restore service?

Governorman—Demonstrate the least possible time required to start a unit from standstill to normal speed without overshooting, at the same time synchronizing with the bus.

How do you know from observation from the floor which unit is carrying the Lancaster load?

Calculate the volume in gallons of the No. 1 hand-controlled sump tank.

Demonstrate raising No. 3 headgate without assistance.

Locate all pump-motor circuits on the direct- and alternating-current power board.

In the event of disturbance, to which main unit should governormen first give their attention? Why?

Demonstrate the opening or closing of one or more transformer neutral ground disconnectors, as given by instructions from operator.

Floorman: How would you continue operation of the station in the event of failure of both direct current and alternating currents to operate the lubricating-oil pump motor?

What is the safe permissible temperature rise in the Kingsbury thrust bearings?

How are the alkalinity and acidity of the governor fluid determined?

Demonstrate the inspection of a governor-regulating valve.

Discuss the types of turbines in the station.

Explain precautions necessary in winter to prevent the 12-in. drainage-pump suction line from freezing.

Discuss the turbine-efficiency test report No. 19.

Machineman—Enumerate the machineman's duties during trouble.

Explain the function of the arc extinguisher relays and the principle of operation.

Make a one-line diagram of the generator and transformer windings and of the type or method of connection.

Diagram the connections to No. 2 governor pump.

Demonstrate the operation of the benchboard and the telephone exchange board.

Diagram the control connections of a General Electric and of a Westinghouse oil switch.

How is the presence of frazil ice in the forebay detected?

Demonstrate synchronizing generators with the bus.

These are a comparatively few of the questions asked. The machineman's examination is made the most thorough of all because a good machineman will invariably make a good operator. The questions asked of the assistant operator and operator are many and varied. The operator is called upon to understand the hydraulic section of the station as well as the electrical section, transmission lines, telephone lines, substations, etc. He is in charge of station operation and has authority over all operators, electrical and hydraulic.

Machinemen in training are sent to the various substations and spend about two weeks learning about the converters, rectifiers, etc., their operation and care. The training of employees at Holtwood is much more thorough than at any other power station the writer has ever visited. Fig. 6 shows the floorman's desk.

One of the striking examples of the value of instruction of the crew and practice by them to establish teamwork is the record time for bringing a main turbine from standstill to running in parallel with the bus. Turbines are brought up to speed on hand-control and when in parallel changed over to governor control. The record time is 26 seconds.

The cheapest method of obtaining nitrogen products for explosives or fertilizers is to procure them from the ammoniacal liquor and gas resulting from the carbonization of coal or its gasification in byproduct gas producers.

The Electrical Study Course—Testing Balancer Sets on Three-Wire Systems

Sets forth the tests to be made on balancer sets when placing them in service for the first time to ascertain whether the connections have been made to obtain the same direction of excitation in both machines.

IN THE preceding lesson the subject of starting balancer sets was treated of. There are, however, some additional points to be observed when such a set is put into service for the first time after being installed, that are worth being discussed.

In the case of shunt machines it is merely necessary to test out the direction of rotation of the two machines and to make the direction of both the same if found to be opposed, but for compound machines the further precaution must be taken that will assure the correct direction of current through the series fields.

The direction of rotation of shunt machines can readily be checked in the following manner: The connections having been made as in Fig. 1 and the switches S_N and S_L being open, the resistance of the field rheostats R_1 and R_2 is all cut out. A piece of wire is then connected as a short-circuit around one of the armatures as indicated by the dotted line C at the armature of G_1. The switch S is closed and the starting switch is then moved momentarily to the first contact, and the direction of rotation of the machines is observed and noted. The short-circuiting connection C is then removed from the armature of G_1 and placed across that of G_2 instead. The starting switch is again closed to the first contact and the direction of rotation of the set noted. If the direction in both cases is the same the machines are ready for service, but if the directions are opposed the field connections of one of them must be reversed. Doing so will change its direction of rotation, since the direction of the current through the armatures remains unchanged. Thus, to reverse field F_1 lead b would be transferred from f to n, and lead d from n to f, or to reverse field F_2 lead c would be changed from g to n and lead e from n to g. It is immaterial which field is reversed since the direction of rotation may be either way.

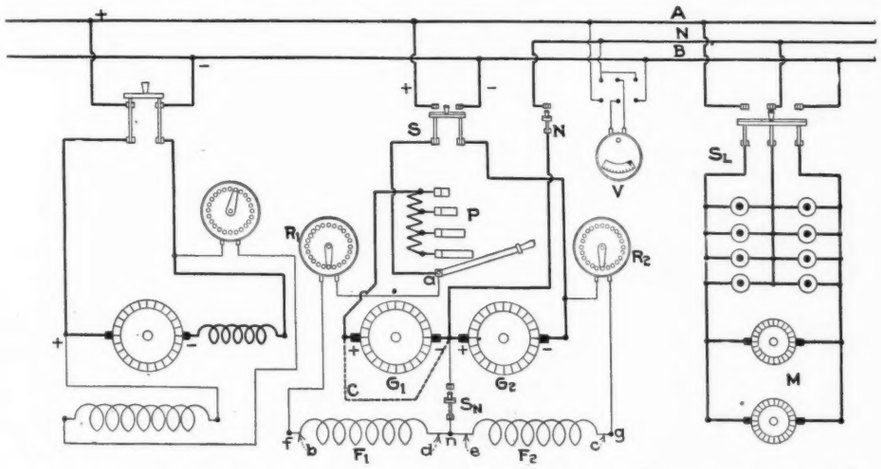


FIG. 1. CONNECTIONS FOR SHUNT BALANCER SET ON THREE-WIRE SYSTEM

It is necessary to short-circuit the armatures as just described, to determine the direction of rotation, since the set would not start if the directions of rotation of the two machines were opposed; G_1 would tend to revolve one way, whereas G_2 would tend to revolve in the other. Owing to the fact that the armatures would not begin to revolve the current through the starting resistance would be of a value to cause serious heating. To make sure of the effectiveness of the short-circuit, the brushes of the short-circuited machine may be removed. It will then be impossible for any current to flow through the armature, as might be the case if the short-circuiting connection had considerable resistance as compared with the resistance of the armature.

When the balancer set consists of compound-wound machines, the connections are those shown in Fig. 2. To test for direction of rotation, the armatures are short-circuited in turn, as described for shunt machines, and the directions of rotation noted. If opposed, they are made the same by reversing the connections of one of the field circuits, as in the case of shunt machines. The next point to be determined is the direction of the excitation due to the series field. It was shown in a previous lesson that the connections must be such as to make the machines differentially compounded when they are operating as motors. It follows that the direction of rotation due to the shunt field alone would be opposite to that due to the series field alone. Consequently, if we observe the directions of rotation when the fields are used separately, we can tell whether the direction of the excitation is as it should be. To do this, we proceed as follows: Suppose, for example, that we are testing machine G_1. We would first open the shunt-field circuit by disconnecting the field wire at m and then short-circuit the armature of G_2 by connecting a wire from d to e. The machine G_1 would now operate as a series motor and it is therefore important to note that the starting switch must not be advanced past the first contact. If more of the starting resistance were cut out, the motor might race badly, and if it were all to be cut out the motor would "run away" since it would be operating as a series machine with load, and with double normal voltage applied.

The direction of rotation should now be the reverse of that observed during the first test. If it is the same, the connections of the series field H_1 should be

reversed; that is, the end that connects to b should be transferred to c, and vice versa. The test must be made on both fields separately since at no load the effect of the shunt field is much greater than that of the series one, and consequently the direction of rotation observed when both fields are operative is that due to the shunt-field excitation.

Having tested machine G_1 and corrected the field connections if necessary, the same procedure is followed with machine G_2. That is, its shunt field is open-circuited and the armature of G_1 short-circuited. The direction of rotation upon trial should then be the same as when G_1 was tested on its series field alone; that is, it should be the reverse of that observed when the first test was made to check the relative rotation of G_1 and G_2. After it has been established that the connections are correct, the set is ready to be put into service.

If the machines are considerably overcompounded, the rush of current at the instant they are started will cause the series-field excitation to greatly reduce that of the shunt field, and consequently the set will speed up very markedly during starting, since the machines are starting on a weakened field. If this action proves to be objectionable, it can be obviated by short-circuiting the series fields while the machines are being started. This can readily be accomplished by connecting them to a double-pole switch, as shown in Fig. 3, or two single-pole switches could be used. Before starting the set, the switch should be closed, thus short-circuiting the series fields. Then, after the machines have been started and are running at normal speed, the switch is opened, thereby allowing the armature current to flow through the series-field windings. Since the current is small when the machines are once running, there will be little effect on the speed. The short-circuiting switch should be opened and the switch S_N closed, so that the machines shall be running under operating conditions when the voltages across each machine are tested preparatory to putting them into service, as discussed in the preceding lesson.

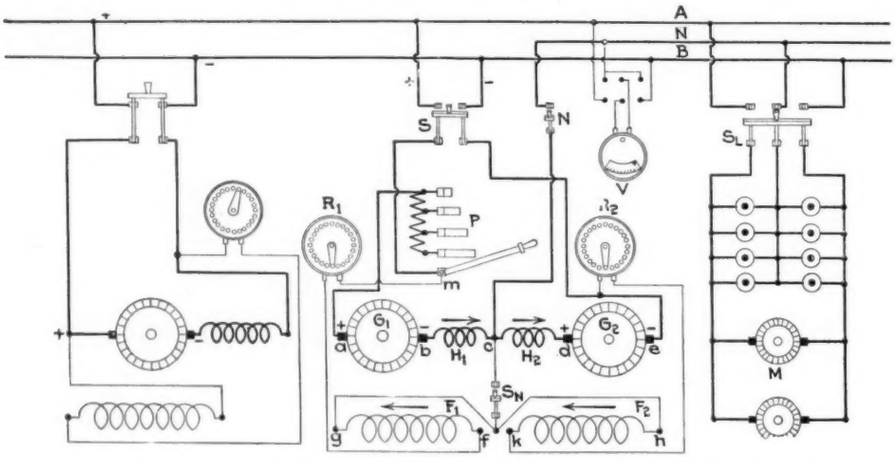


FIG. 2. CONNECTIONS FOR OPERATING A COMPOUND-WOUND BALANCER SET ON A THREE-WIRE SYSTEM

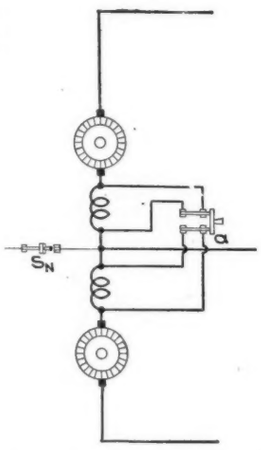


FIG. 3. SHORT-CIRCUITING SWITCH ON SERIES FIELDS

In the preceding problem we have given a 110- to 220-volt three-wire system as in Fig. 4. The loads L_1 and L_2 are composed of lamps and take 120 amperes and 180 amperes respectively. The load M consists of motors taking a current of 230 amperes. It is required to find the value and direction of the currents I, I_A, I_B, I_N, I_1 and I_2 in the various parts of the circuit, if the machines G_1 and G_2 take 10 amperes. The total load supplied from the 220-volt source is the sum of all the loads upon it. The load L_1 is equal to 120 amperes $\times$ 110 volts = 13,200 watts, L_2 is equal to 180 amperes $\times$ 110 volts = 19,800 watts, M is equal to 230 amperes $\times$ 220 volts = 50,600 watts, and the load due to G_1 and G_2 is 10 amperes $\times$ 220 volts = 2200 watts. The total load is therefore 13,200 + 19,800 + 50,600 + 2200 = 85,800 watts, and this divided by the supply voltage, namely, 220 volts, gives the line current; that is, $I = \frac{85,800}{220} = 390$ amperes. The current I_A is the sum of the load currents of L_1 and M, or $I_A = 120 + 230 = 350$ amperes. Similarly, I_B is the sum of the load currents of L_2 and M, or $I_B = 180 + 230 = 410$ amperes. The current in the neutral is their difference, or $I_N = 410 - 350 = 60$ amperes. The directions of these various currents is that of the arrows in the figure. Since $I = 390$ amperes and I_A is only 350 amperes, we have $I_1 = 390 - 350 = 40$ amperes, which flows through G_1 from plus to minus; that is, G_1 runs as a motor. On the other hand, $I_2 = I_B - I = 410 - 390 = 20$ amperes, and since I_B is larger than I, the current must flow through G_2; that is, G_2 operates as a generator.

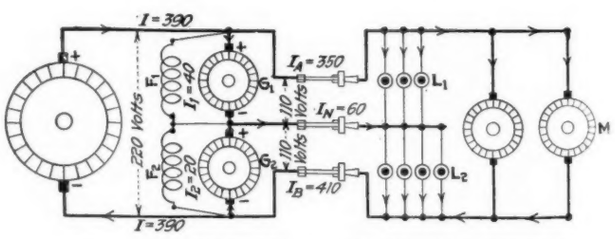


FIG. 4. THREE-WIRE, 110- TO 220-VOLT SYSTEM

It was also required to find the size of machines necessary to use in the balancer set if the total lamp load on each side amounted to 200 amperes and the system was liable to be completely unbalanced at times. When completely unbalanced, G_1 and G_2 would have

to take care of the load on one side; namely, 200 amperes. Half of this would pass through each machine. Disregarding the losses in the machines, they would each have to be of 100 ampere capacity at 110 volts, or $100 \times 110 = 11{,}000$ watts; that is, 11 kw. It would therefore be safe to install 10-kw. generators, as these would readily stand the overload for such periods as it might last.

A 220-volt generator is to be used in connection with a 110- to 220-volt three-wire system. Its current rating is 455 amperes. How many 40-watt lamps can be supplied without overloading the generator? If a 220-volt motor load takes 60 hp., how many lamps can the generator supply in addition to the motor load? What size of wire should be used for the neutral in the latter case?

Refrigerating Plant Data

Several tables, including those on properties of saturated and superheated ammonia, brine solutions, their freezing temperatures and specific heat, are given, also some practical rules for piping and other information needed by the operator of the refrigerating plant.

USUALLY, the engineer of the common-sized ice and refrigerating plant using ammonia does not take the trouble to provide himself with a refrigerating engineer's handbook. The following data are here arranged for the use of such men, although they are by no means meant to take the place of a handbook or textbook or combination of both; the aim is to give him some of the chief figures and values for which he has use in those problems which from time to time vex him.

Some Properties of Ammonia

Commercial Ammonia is a solution of ammonia gas in water. The usual strength is 26 deg. Baumé, containing about 38.5 per cent. of anhydrous ammonia.

Boiling Point—At atmospheric pressure commercial ammonia boils at —29 deg. F.

Heat of Vaporization of Ammonia—At atmospheric pressure, 593 B.t.u.

Unit of Refrigerating Capacity—200 B.t.u. per min.; 12,000 B.t.u. per hour; 288,000 B.t.u. per ton of ice melted. The refrigerating capacity of a compressor or absorption machine is more than the actual ice-making capacity by 50 per cent. or more, depending upon the temperature of the water and other less important factors.

TABLE I. PROPERTIES OF SATURATED AMMONIA

(From tables of Goodenough and Mosher)

Temp., Deg. F.	Pressure, Lb. per Sq. In. Abs.	Specific Volume Saturated Liquid, Cu.Ft. per Lb.	Specific Volume Saturated Vapor, Cu.Ft. per Lb.	Heat Content Liquid	Heat Content Saturated Vapor	Heat of Vaporization, B.t.u.
—40	10.12	0.0234	25.45	—75.3	526.6	601.9
—35	11.74	0.0235	22.14	—70.2	528.2	598.3
—30	13.56	0.0236	19.35	—65.0	529.8	594.7
—25	15.61	0.0238	16.95	—59.8	531.3	591.1
—20	17.91	0.0239	14.89	—54.6	532.8	587.4
—15	20.46	0.0240	13.15	—49.4	534.3	583.6
—10	23.30	0.0241	11.63	—44.2	535.7	579.9
— 5	26.46	0.0242	10.32	—38.9	537.1	576.1
0	29.95	0.0244	9.19	—33.7	538.5	572.2
5	33.79	0.0245	8.20	—28.4	539.9	568.3
10	38.02	0.0246	7.34	—23.2	541.2	564.4
15	42.67	0.0248	6.583	—17.9	542.5	560.4
20	47.75	0.0249	5.920	—12.6	543.7	556.3
25	53.30	0.0250	5.336	— 7.3	545.0	552.2
30	59.39	0.0252	4.820	— 1.9	546.2	548.1
35	65.91	0.0253	4.364	+ 3.5	547.4	543.9
40	73.03	0.0255	3.959	8.9	548.5	539.7
45	80.75	0.0256	3.599	14.3	549.7	535.3
50	89.0	0.0258	3.278	19.8	550.8	531.0
55	98.0	0.0259	2.992	25.3	551.9	526.5
60	107.7	0.0261	2.734	30.9	552.9	522.0
65	118.0	0.0263	2.503	36.5	554.0	517.0
70	129.0	0.0264	2.296	42.1	555.0	512.8
75	141.0	0.0266	2.109	47.8	556.0	508.1
80	153.9	0.0268	1.904	53.6	557.0	503.4
85	167.4	0.0270	1.788	59.4	557.9	498.5
90	181.8	0.0271	1.650	65.3	558.9	493.5
95	197.0	0.0273	1.524	71.3	559.8	488.5
100	213.0	0.0275	1.408	77.3	560.7	483.4
110	249.6	0.0280	1.305	89.6	562.5	472.9
115	269.2	0.0282	1.122	95.9	563.3	467.4
122	300.0	1.007	0.993	105.3	564.6	459.3

TABLE II. PROPERTIES OF SUPERHEATED AMMONIA

(From tables of Goodenough and Mosher)

Pressure, Lb. per Sq.In. Abs.	Temp. of Saturated Vapor, Deg. F.		Superheat, Deg. F. 20	40	60	80	100	150	200
20	—15.9	U	14.2	14.9	15.6	16.3	16.9	18.6	20.2
		H	545.2	556.1	566.7	577.1	587.4	612.7	638.0
40	12.2	V	7.40	7.76	8.12	8.46	8.80	9.64	10.46
		H	553.9	565.5	576.8	587.7	598.3	624.6	650.6
50	30.5	V	5.04	5.30	5.54	5.77	6.01	6.57	7.12
		H	559.1	571.2	582.9	594.2	605.2	632.1	658.6
80	44.5	V	3.85	4.04	4.22	4.40	4.57	5.00	5.42
		H	562.8	574.3	587.4	599.0	610.3	637.7	664.6
100	56.0	V	3.10	3.26	3.41	3.56	3.70	4.05	4.38
		H	565.7	578.6	590.9	602.8	614.3	642.2	669.4
120	65.8	V	2.61	2.74	2.87	2.99	3.11	3.40	368.8
		H	568.2	581.4	593.9	605.9	617.6	646.0	673.4
140	74.5	U	2.25	2.37	2.48	2.58	2.69	2.94	3.17
		H	570.2	583.6	596.4	608.7	620.6	649.3	676.9
160	82.3	U	1.98	2.08	2.18	2.27	2.36	2.58	2.79
		H	572.0	589.7	598.6	611.1	623.2	652.1	680.1
180	89.4	U	1.77	1.86	1.94	2.03	2.11	2.31	2.49
		H	573.6	587.5	600.6	613.2	625.4	654.7	682.8
200	95.9	V	1.59	1.67	1.75	1.83	1.90	2.08	2.25
		H	575.0	589.1	602.4	615.2	627.5	657.0	685.4
250	110.1	V	1.28	1.35	1.41	1.47	1.53	1.68	1.81
		H	578.0	592.4	606.1	619.3	631.9	661.9	690.8
300	122.4	V	1.07	1.13	1.18	1.23	1.28	1.41	1.52
		H	580.5	595.3	609.3	622.7	635.5	666.1	695.4

Volume of Ammonia Gas To Be Handled by Compressor (F. L. Fairbanks in Marks' Handbook)—The volume of dry saturated gas (cu.ft. per min.) that must be handled by the compressor to produce 1 ton of refrigeration per day of 24 hours is $V = \frac{200\,V''}{(r - i')}$ where V'' = cu.ft. per lb. at evaporating pressure, r = latent heat at evaporating temperature and pressure, and i' = heat of the liquid between the limiting pressures:

Example: Head pressure, 199 lb. abs.; back pressure, 29.95 lb. abs. Then $r = 572.2$ B.t.u. and i' 106.6 B.t.u. Also $V'' = 9.19$ cu.ft. per lb. The weight of ammonia per minute $= \frac{200}{(572.2 - 106.6)} = 0.4295$ lb., and cu.ft. per min. $= 0.4295 \times 9.19 = 3.95$. Assuming the volumetric efficiency of the compressor equals 80 per cent., the actual piston displacement $= \frac{3.95}{0.80} = 4.93$ cu.ft. per ton of daily capacity.

Volumetric Efficiency is the ratio of the actual weight of vapor handled by the compressor to the weight calculated from the displacement of the compressor with gas entering at its evaporating pressure; it varies from 60 to 85 per cent. Compressor builders will guarantee 80 to 85 per cent. in machines of 50 tons and over.

Weight of Ammonia Required by Compression System—To estimate the total quantity of anhydrous ammonia required, allow that the condenser space is filled with ammonia vapor at 165 lb. pressure; that the entire volume of the cooler coils is filled with vapor at 20 lb. pressure; for every cubic foot of liquid receiver capacity allow 25 lb. of liquid ammonia.

Practical Rules for Direct-Expansion Piping (F. L. Fairbanks)—One lineal foot of 2-in. pipe to 10 cu.ft. of space in rooms maintained between 32 deg. and 10 deg. F.; one lineal foot to 40 cu.ft. of space in rooms kept between 32 deg. and 50 deg.; one lineal foot to 60 cu.ft. space in rooms kept at 50 deg. F. or above. These values are liberal. One ton refrigerating capacity is a liberal allowance for every 4500 cu.ft. of cold-storage capacity held at 32 deg. F. For every ton of refrigeration allow 260 to 300 ft. of 1¼-in. pipe. Luhr suggests 600 lin.ft. of 2-in. pipe per ton refrigeration for direct-expansion systems, and 750 ft. for brine systems. For storage rooms he allows one foot of 2-in. pipe per 25 cu.ft. of space; for freezing rooms, one foot of 2-in. pipe per 7 cu.ft. space; for fish freezing rooms, one foot of 2-in. pipe per 2 cu.ft. of space.

TABLE III. FREEZING TEMPERATURES OF BRINE AT VARIOUS SOLUTION STRENGTHS

Calcium Chloride			Sodium Chloride			
Specific Gravity	Deg. Baumé at 64 Deg. F.	Approx. Weight of Salt Required, Lb. per Gal.	Specific Gravity	Deg. Baumé at 64 Deg. F.	Approx. Weight of Salt Required, Lb. per Gal.	Freezing Point, Deg. F.
1.035	5.0	1.00	1.022	3.0	0.21	28
1.062	8.6	1.5	1.044	6.0	0.52	24
1.085	11.4	1.75	1.067	9.0	0.80	20
1.113	14.7	2.00	1.091	12.0	1.1	16
1.122	15.9	....	1.117	15.2	1.4	12
1.139	17.9	....	1.142	18.0	1.8	8
1.155	19.7	2.5	1.168	20.9	0.2	4
1.165	20.7	3.25	1.193	23.5	2.8	0
1.174	21.7	....	.....	....	....	— 4
1.186	23.0	3.5	.....	....	....	— 8
1.197	24.1	....	.....	....	....	—12
1.207	25.2	4.0	.....	....	....	—16
1.216	26.1	4.25	.....	....	....	—20

TABLE IV. SPECIFIC HEAT OF BRINE

Sodium Chloride		Calcium Chloride	
Specific Heat, B.t.u.	Specific Gravity	Specific Heat, B.t.u.	Specific Gravity
0.78	1.200	0.98	1.024
0.86	1.100	0.91	1.076
0.94	1.050	0.86	1.121
0.98	1.020	0.83	1.179
....	.....	0.79	1.219
....	.....	0.77	1.240

Brine Velocity—This should be kept below 180 ft. per minute.

Capacity of Compressor, Tons (Luhr)—The formula is for the theoretical capacity; deduct 25 per cent. for the actual capacity:

$$T = \frac{d^2 \times 0.7854 \times S \times 2 \times r \times h \times 1440}{1728 \times 288{,}000}$$

in which

T = Tons refrigeration in 24 hours;
d = Diameter of compressor in inches;
S = Stroke in inches;
r = Revolutions per minute;
h = Refrigerating effect of one cubic foot of refrigerant at refrigerator pressure, completely evaporated from liquid at condenser pressure.
1440 = Minutes in 24 hours.
288,000 B.t.u. equivalent of one ton of refrigeration.

Example: Find the capacity of a double-acting compressor 9⅞ in. x 16⅞ in. stroke, 70 r.p.m.; suction pressure, 25 lb. gage; discharge pressure, 165 lb. gage.

Solution: The refrigerating effect of one cubic foot of ammonia vapor expanded between the given pressures is 67.1.

$$T = \frac{9\frac{7}{8} \times 9\frac{7}{8} \times 0.7854 \times 16\frac{7}{8} \times 2 \times 70 \times 67.1 \times 1440}{1728 \times 288{,}000}$$

$$= 35.42 \text{ tons in 24 hours.}$$

TABLE V. AMMONIA CONDENSER DATA

(For clean, unobstructed, free of air and foul gases, 70 deg. F. water, 200 lb. abs. pressure)

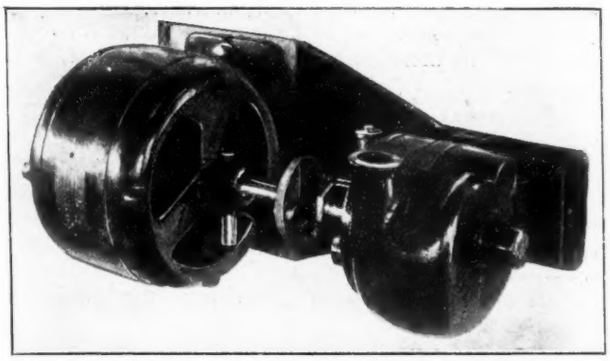
Type	Surface per Ton Refrigeration, Sq.Ft.	Heat Transmission per Sq.Ft. per Min. per Ton Refgeration	Pipe per Ton Refrigeration Common Size, In.	Lineal Ft.	Water Required per Min. per Ton, Gal.
Atmospheric	24	8.5	2	45	2 to 3
Flooded atmospheric	6	33	2	11	1½ to 2
Flooded double-pipe	8	25	1½	22	1½ to 2
Double-pipe	8	25	1¼	22	1½ to 2
Coil	16	12	2 to 1¼	30 to 45	2.5
Tube	18	11	1¼	55	2 to 3
Submerged	35	5.7	2	65	4 to 7

Actual Horsepower Required per Ton of Refrigeration (Luhr)—The horsepower varies from 1.25 to 2 hp. per ton refrigeration, varying with size and condenser and suction pressures. On the average a 6-ton machine requires 2 hp. per ton, a 25-ton 1.54 hp. per ton, a 50-ton 1.27 hp. per ton, and a 100-ton 1.25 hp. per ton.

A 1000-ton compressor in the Quincy Market plant, Boston, at 750 tons capacity produced a ton refrigeration on 0.9 hp., compound condensing Corliss engine. A 400-ton machine, in the same plant gave a ton capacity for 1.25 horsepower.

"Fulflo" Motor-Driven Pump

The motor-driven lubricant pump shown in the illustration has just been placed on the market by the Fulflo Pump Co., Blanchester, Ohio. This pump is built in ⅜-, ¾-, 1- and 1¼-in. sizes arranged for either floor or wall mounting and is equipped with ⅛-, ⅓-, ¾- and 1-hp.



"FULFLO" MOTOR-DRIVEN PUMP

motors respectively. The pump shown in the illustration is the ¾-in. size equipped with a ⅓-hp. motor running 2700 r.p.m. The capacity at this speed is 21 gal. per min. with an 11-ft. head, 20 gal. per min. with a 12½-ft. head, and 11 gal. per min. with a 24-ft. head. The pump, of the centrifugal type, having both intake and outlet at the top, retains enough fluid for priming purposes.

The impellers are of the semi-inclosed type and are supported by a bearing at either end of the impeller shaft, the thrust on the suction side of the impeller being taken care of by a hardened-steel thrust collar on the shaft, which turns against the nose of the bronze bushing supporting the impeller shaft on the suction side of the pump. The main pump bearing also forms the pump gland and is of cast iron. The lubrication of this bearing is taken care of by a sight-feed oiler which feeds into a pocket surrounding the bearing.

The pump is attached to the base by six screws, three of which extend through the motor and pump base and three through the motor base only, the pump base resting on their points. This construction makes it possible, by adjusting these screws, to bring the pump into line with the motor; then the screws are locked in place.

Curing a Chronic Case of Cracked Head

By D. L. FAGNAN

ERECTORS of oil and gas engines in their experience become familiar with a wide range of troubles and the remedies employed to overcome them. In the case of at least one company manufacturing such engines, the erecting engineers and troublemen get together at stated intervals, exchange experiences and discuss new and up-to-date methods of erection, trouble chasing, kinks and ideas which they have learned during their absence on important jobs. These meetings tend to keep the men in touch with new developments and bring about distribution of knowledge. Each man contributes his share, and if he is sensible absorbs his share, of the valuable experiences.

One of the most interesting incidents in my own experience as a troubleman and erector was a case of cracked head in a Diesel engine of 225 hp., operating in the power plant of a suburban railroad. There were two engines, of the three-cylinder vertical type, but only one of them was chronically troubled with cracking of the head. Five of these heads broke in a period of three months, and the company wished as heartily as the owner that the cause could be found and the trouble remedied.

In passing through the city in which this plant was located, I dropped in casually and learned of the trouble that had been experienced. However, as my time was limited, I had opportunity for only a brief examination of the plant, during which I detected nothing wrong. Consequently, I had no chance to help them out and so simply reported the matter to the home office on the daily report sheet. Shortly afterward the home office received an urgent message to send two new heads as well as a man to locate the trouble and prescribe a remedy. As I was the nearest man to this locality, I received orders to rush there at once and set things right.

Noting Temperature of Cooling Water

My first move was to get a line on the water-cooling system. I observed the piping layout and the valve system on the manifold and noted the temperatures at the inlet and the outlet from the cylinders. There was only one thermometer on the main inlet to each engine, but a thermometer was provided on each outlet from each cylinder head. With the inlet water having a temperature of 56 deg. F., the temperatures at the outlets were 130 deg., 136 deg. and 145 deg. on cylinders Nos. 1, 2 and 3, respectively. These temperatures were observed with the engine running under normal conditions. Five minutes after shutting down, the outlet temperatures were found to be 96 deg., 105 deg. and 120 deg. respectively. These figures indicated a considerable variation in temperature.

As all of the valves were open wide, something was evidently radically wrong about the manifold or the piping. The first thing that entered my mind was that the burrs had not been removed from the nipples or the piping after cutting with an old-style pipe cutter. It also occurred to me that, in combination with the foregoing trouble, pipe scale or an accumulation of rubbish in the manifold might have caused a restricted opening, thus allowing only a small supply of water to pass into the farthest cylinder. Accordingly, the manifolds of the engine were entirely dismantled, all nipples reamed out, and all ells and tees cleaned thoroughly and reassembled.

The water plugs on the head and water jacket were removed, and all accumulation of sludge removed with a hose. Then a 10 per cent. solution of muriatic acid was run in. A system of piping was rigged up to catch the solution after it had lain in each cylinder head for a few hours, since the acid solution may be used repeatedly by strengthening it occasionally with acid. It is very effective in removing scale from intricate passages and eats away the usual scale very quickly, causing effervescence while it is acting; but the cylinder head must be washed out clean immediately after the acid solution is removed.

Proposed Water-Softening Equipment

We next inspected the water supply and found that it came from an artesian well. The tank containing the cooling water held about 2000 gal., and the water was cooled by means of a home-made cooling tower, which was very effective, as the weather was quite cold. My proposal was to soften the water with a drum of aqua ammonia that was in the plant. This ammonia was worked into the cooling-water line gradually, but as the plan was only a makeshift, I proposed that they consult a chemist in regard to softening the water. For it was my opinion that a combination of scale and a scant supply of water due to obstruction had caused local overheating and cracking of the cylinder head at the bridges and the ports.

The engineer was in the habit of allowing the circulating water to flow for five or ten minutes after stopping the engine, and no fault could be found with the method of operating the plant. Everything finally seemed all right, so I watched the outlet temperatures carefully, manipulated the several valves so as to give uniform outlet temperatures, and then fixed these valve settings permanently, since one main water valve served to start and stop the circulation.

On the third day after my arrival, I considered conditions permanently remedied. Six months later I wrote to the plant to find out if any new difficulty had arisen and they replied that no further trouble had occurred. Meanwhile, they had installed a water-softening system of home-made design that had proved successful. It was practically a distilling system receiving heat from the hot exhaust gases.

My experience indicates that the cracking of cylinder heads occurs after the engine is shut down and is due to the contraction of the cooling metal after the water supply has been stopped and not to expansion caused by overheating.

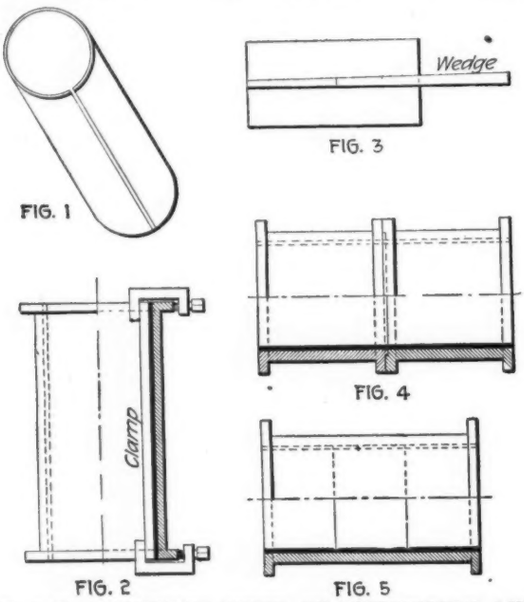
Some engineers claim that 125 deg. F. is the highest allowable outlet temperature for the jacket water; others say 110 deg. is correct, and still others insist that 160 deg. is not too high. My experience indicates that if the water tends to form scale in the heads and jackets, 90 deg. is a good temperature. If the water is free from scale, go higher, even to 160 deg., as fuel economy is increased thereby. If piston-pin bearings give trouble by overheating, then the outlet temperature should be lowered.

Composition Lined Cylinders

By A. M. STILES

CYLINDERS lined with a noncorrosive metal are necessary in the construction of air pumps and hydraulic valves. They are also extensively used on the water ends of piston pumps. These liners can be made of standard tubing where the diameter does not exceed 16 in. In the design of air pumps for condenser service, where the pump is driven by a projecting bracket of the main pump (which is standard practice in water-works construction), or in hydraulic valves, where the stroke or lift is dependent upon the size of the valve, the volume of the cylinder will depend upon its diameter, which then becomes an exact dimension not obtainable in the standard sizes of tubing.

Sheet stock can be advantageously used for cylinders of this type, the diameters being limited only by the length of the sheet obtainable. The cylinder is bored to the required size with an allowance for the thickness of liner stock, which should be at least $\frac{1}{4}$ in. thick for



FIGS. 1 TO 5. VARIOUS TYPES OF COMPOSITION LINERS

cylinders over 20 in. in diameter and in no case less than $\frac{3}{16}$ in. The sheet is then rolled, as shown by Fig. 1, in the direction of its length to a diameter that will permit it to fit freely but snugly into the cylinder. The ends of the sheet must not touch after rolling, but should be open from $\frac{1}{8}$ to $\frac{5}{8}$ in. for cylinders from 18 to 40 in. in diameter. If, after rolling, the edges touch or are not parallel, they can be planed or milled.

The liner is then dropped into the cylinder and stayed by clamps, as shown in Fig. 2, from three to six equidistantly spaced clamps being used, the number depending on the size of the cylinder. The entire inside surface is then peened to bring the metal in close contact with the cylinder wall and to close the space between the ends of the liner. The peening operation is started opposite the slot and worked from the center to the ends, the clamps being removed to new positions to permit peening under them. When the edges of the sheet touch, the clamps may be removed altogether. The final blows of the hammer cold-weld this seam, making it tight and nearly invisible. A finish cut is necessary, and, if the peening has been evenly and carefully done, no more than $\frac{1}{32}$ in. of metal need be removed.

Another method of using the sheet-stock liner is shown by Fig. 3. After the liner is rolled to the correct diameter, the edges are planed taper to receive a wedge of the same stock. This wedge is about $1\frac{1}{4}$ in. wide and tapered about $\frac{1}{16}$ in. per foot of length. After the liner is placed in the cylinder, the wedge is driven home, forcing the liner against the cylinder wall, after which it is peened all over as in the first case. This method involves more machine- but less floor-work than with the single piece. Two seams are not an objection as they are tight and the clamps are dispensed with.

The use of sheet stock insures contact between the inner cylinder wall and the outer surface of the tube, for the peening operation, after the edges of the liner touch, increases the diameter to a much greater tolerance than could possibly be allowed for a press fit where the liner is cast in tube form and turned up. For instance, if 0.001 in. excess diameter were allowed for drive in a cylinder 25 in. in diameter by 40 in. stroke the liner would probably buckle in driving it home, owing to the friction set up by its length, and it is usual to allow nothing at all for drive, but to turn the liner to the exact bore of the cylinder; there is, therefore, no pressure exerted by the liner at right angles to the cylinder axis irrespective of the pressure required to drive it home, a condition that is conducive to leaks and corrosion of cylinders walls. Sheet stock has the further advantage of high tenacity and malleability.

Owing to the scarcity of both tubes and sheet stock during the war, cast liners were often used with good results, although perfect castings are difficult to make even when cast $\frac{1}{2}$ in. thick, because of the uneven proportion between the thickness, diameter, and length and the excessive shrinkage of composition stock.

Fig. 4 shows the construction of two 36 x 80-in. hydraulic valve cylinders made for the St. Louis Water Department. Both cylinders and liners are cast in two sections to simplify the foundry work. A male and female groove is turned in the cylinder sections to keep them in alignment. The liners were cast in a vertical position and, having a thickness of $\frac{7}{16}$ in. when finished, were forced into the cylinder sections.

Fig. 5 shows the method of lining fifteen 26 x 42-in. cylinders also used for valves; in this case the cylinders were cast in one piece, but the liners were made up in three sections as shown; they were cast $\frac{1}{2}$ in. thick, finished to $\frac{9}{32}$ in., turned to a diameter that would permit them to fit freely into the cylinder and peened all over to insure contact with the cylinder wall. The edges were beveled, as shown, about $\frac{1}{64}$ in. to insure a tight joint next the iron. This bevel was closed by the peening operation, and after the finish cut was taken no joints were visible. These sections were also cast vertical, and their comparatively small size permitted rapid production both in the foundry and shop without the use of special and heavy apparatus necessary for the single tube. There was also an improvement in the quality of the castings.

EDITORIALS

The Mobile Boiler Explosion

THE Mobile explosion described on page 432 *et seq.* is one of the most notable of recent years. Although but two boilers apparently exploded and only four were thrown from their settings, the toll in lives and property of the explosion and the fires which followed was greater than that which has resulted from explosions in which more boilers were involved.

Out of the tangled mass of drums, tubes and headers yielded up by the débris it is possible to deduce the fact that two of the boilers were ruptured in such a way that either might have been the source of the trouble. A Heine failed by breaking off the rear drum head and the back water-leg through the upper line of tube- and hand-holes, and splitting the drum longitudinally through the solid sheet. A Stirling failed by blowing out the closed end of its mud drum by one of those circular fractures around the crown of the flange about which there has been so much discussion and which have shared with the lap-joint crack the responsibility for a number of the recent serious accidents. The Heine had been in operation about fifteen and the Stirling about twenty-two years.

Which rupture occurred first? Which was responsible for the wreck of the other? These are questions that are likely never to be answered positively, for the clearing up was promptly commenced, and the location to which some of the boilers and fragments were projected cannot be determined.

If the explosion had been general, the finding of such a positive proof of rupture as the disk from the Stirling drum head would seem to fix the initial fracture. The fact that only one Heine exploded, and this with considerable violence, gives plausibility to the claim that it may have been the first to explode and that the shock caused the blowing out of the weakened end of the Stirling drum. The direction taken by the Stirling supports this view, although No. 6 might have landed where shown, by exploding against No. 5 and the latter then have been projected to its location by the subsequent explosion of the Heine. The two closed heads of the Stirling drum were in line with each other in the partition wall. The head from No. 5, which should have received the impact of that from No. 6 if the latter blew out while the drum was still in place, was found uninjured, but we do not know where. It would have been shielded from direct impact by the division wall. The location of the disk from No. 6 would be enlightening if it could be determined.

The water in a boiler at one hundred and sixty pounds pressure has a temperature of over three hundred and seventy degrees. When the pressure is reduced to that of the atmosphere, about fifteen per cent. of the water flashes into steam with an instantaneous swelling of the contents to the full capacity of the containing vessel, with a water-hammer result similar to that which would be produced by filling the boiler completely with water, putting a loosely fitting plug into the steam nozzle and dropping the hammer of a pile driver on it. The explosion of seven Heine boilers at St. Louis in 1904 was evidently caused in this way. The breaking of a steam main released the pressure suddenly, and the seven boilers were scattered over a wide area. The destruction of one of the boilers was much more complete than that of the rest. It was rent and torn, not through the seams and the obviously weakest points, but through the solid sheet in the back end of the main drum.

The exploded Heine boiler in this case has evidently been subjected to some such violent action. The drum is torn through the solid sheet and the magnitude of the forces involved is evidenced by the enlargement of many of the stay-bolt and other holes.

The question of the possible failure of the Heine boiler from excessive pressure is raised. The recording pressure gage upon the system shows a pressure of a little over one hundred and sixty pounds at the time of the explosion. There was one or more automatic return valves in the steam line, but information as to whether the arrangement was such that its sticking would allow an excessive pressure to build up in one or more of the boilers is not at hand.

Whether the Stirling went first or not, it had in its weakened head the possibility of failure at any time. This is no discredit to the boiler which had twenty-two years of service to its credit, but to the setting of the head in such a position that it was practically inaccessible for inspection.

We shall seek further information and present it as obtained. In the meantime our readers may have pertinent knowledge or ideas, which are solicited for our correspondence columns.

Reading a Watt-Hour Meter

TOO often is the important matter of reading a wattmeter trusted to an unskilled or careless reader, who reports a certain amount of energy used, and the customer is billed or the department charged accordingly. The customer pays his bill without protest with the result that neither the electric company nor the user is any the wiser. So it behooves the efficient operating engineer who has electrically operated machinery, to read the meter and satisfy himself that he is getting all the energy for which he pays or that he is not basing operating costs on a low cost of energy due to a wrong electric bill.

That this subject is of vital importance is shown by the fact that such an error in reading was the basis of an extensive lawsuit involving thousands of dollars. An electric company supplied energy to a consumer only a few miles from New York City, and made an incorrect charge. Each month they forgot to multiply the reading by a constant of ten, resulting in a billing to the consumer of only one-tenth of his correct bill. The consumer used the electric-energy charge in computing the cost of his product. When, after some time, the electric company discovered its mistake and billed the customer for the descrepancy, payment was refused, which resulted in a lawsuit and a dissatisfied customer.

The article on "How to Correctly Read a Watt-Hour Meter" in this issue, is not at all technical and treats the subject in such detail that this seemingly complicated matter is rendered easy to master. It deals with the different forms of watt-hour meter dials used by various manufacturers, telling what the various markings mean, and gives simple instructions by which the layman can readily tell how much electric energy he has used and how much his bill will be.

United States Nitrate Plant Number Two

BEGINNING in this issue we publish the first of several articles descriptive of the new steam station of United States Nitrate Plant Number Two at Muscle Shoals, Alabama. This is the steam station for the large nitrate plant of the United States Government and is truly one of the most interesting power stations ever built. As pointed out in the article, the conditions on which the engineers based their design are so close an approach to the ideal that one must have this thought in mind when considering the performance results expected by all who know the plant well.

The plant's history is illuminating. In the fall of 1917 the United States War Department was faced with a serious problem: The supply of nitrogen available for the manufacture of high explosives was found to be a small fraction of the amount required to meet the munitions program for the rapidly increasing army.

In modern warfare it is the rate at which ammunition is used that wins battles and wars. In the war on the western front about two tons of ammunition were used for each soldier killed, captured or seriously wounded. Increasing the rate at which ammunition was sent to the front would perhaps have saved one soldier for each extra two tons of ammunition. It was then a question of speed of munitions manufacture against men. Upon the Production Division of the Ordnance Department was placed the serious and difficult responsibility of obtaining, without fail, an enormous quantity of high explosives to meet a tremendous military program.

Every military explosive is a nitrogen compound made from nitric acid or ammonia, or both. Military explosives are of two classes—propellants for hurling projectiles and high explosives for bursting the shells or bombs. The high explosives used are TNT (trinitro-toluol) made from toluol and nitric acid; picric acid, made from benzol and nitric acid; and ammonium nitrate, made from ammonia and nitric acid. It was the shortage of these high explosives that threatened to hold up the munitions program.

Toluol and benzol were obtainable only in small quantities as byproducts of the coking of coal. The entire production could furnish only a small fraction of the requirements. The cost of TNT and picric acid was about two and one-half times the cost of ammonium nitrate from ordinary sources; therefore the Ordnance Department preferred to increase the supply of ammonium nitrate to mix with the TNT.

The only existing sources of ammonia, however, were the byproduct coke ovens and gas works. The capacity of ovens had already been doubled since the beginning of the war. The cost of construction had risen to about two and one-half times normal. To furnish the amount of ammonia needed, another doubling of capacity would have been required, so that the final outlay would probably have been several hundred million dollars. The period required for the construction would undoubtedly have postponed the entire military program.

To get the other material required—namely, nitrate of soda—would have placed additional heavy demands upon the supply of ships, already seriously reduced by the submarine campaign. The conversion of the nitrate to nitric acid would have required concentrated sulphuric acid, ton for ton, and the sulphuric-acid supply was far behind the requirements. All these large-scale operations, the building of ovens, the coking of great additional tonnages of coal, the hauling of the ammonia liquors, the nitrate and the sulphuric acid would have placed a stupendous burden upon the already overloaded railroads.

In this emergency, in the fall of 1917, the American Cyanamid Company, on invitation, laid before the Ordnance Department a plan for the manufacture of ammonium nitrate from the common materials, limestone, coal, coke and air. One or more plants, each complete in itself, could be built within twelve months, to supply the entire quantity of ammonium nitrate desired, and at less than one-half the prevailing cost.

The practicability of producing ammonia and nitric acid from the air for the manufacture of explosives had indeed already been a subject of investigation by the Nitrate Supply Committee of the War Department. A plant using a modified Haber process was under contract to be erected at Muscle Shoals, Alabama, with a capacity equal to 22,000 tons of ammonium nitrate per annum. This plant, known officially as United States Nitrate Plant No. 1, was being built under a Congressional appropriation of twenty million dollars made about a year and a half previously. Several other new processes also were to be tested here. Inasmuch, however, as none of the processes to be used at Plant No. 1 had ever operated commercially, and would not therefore be fully depended upon, the Ordnance Department, with its tremendous responsibility, was unwilling to consider the extension of any of these processes as a solution of its problem.

Fortunately, the dependability of every step in the cyanamid processes had already been proved by actual commercial operations over a period of years.

At the request of the War Department, the American Cyanamid Company formed a subsidiary corporation, known as the Air Nitrates Corporation, to act as the agent of the United States Government for the construction and operation, under the cyanamid processes, of a plant at Muscle Shoals, Alabama, to produce 110,000 tons of ammonium nitrate per annum. This plant is known as United States Nitrate Plant No. 2. Construction was determined upon November 16, 1917. The first carload of material was delivered December 20, and the first ground was broken February 16, 1918. More than thirty thousand men were employed on construction at its peak.

The plant began operating October 23, 1918, eight months after ground was broken. The site occupies 2200 acres, including a permanent village built to accommodate twelve thousand people. The additional plants, each with one-half the capacity of the Muscle Shoals plant, were also contracted for in July, 1918, to be built and operated for the Government by the Air Nitrates Corporation. Work on these plants was abandoned after the signing of the armistice. In a little over one year of actual construction work, therefore, the country would have acquired a cyanamid-nitrates production

equal to the total production of ammonia from all sources in this country at the time construction was decided upon.

While the station embodies the most modern practice in every respect, the reader should have before him the thought that the ideal conditions encountered have influenced design accordingly. Economizers were not installed although provision has been made for their convenient installation, should conditions warrant them. The house turbines are operated noncondensing, and practically all auxiliaries and the service pumping station are electrically driven, realizing the high efficiency of this form of drive.

Original plans called for a plant of 90,000 kilowatts—one 60,000-kilowatt and one 30,000-kilowatt turbine of the reaction type. The former is installed and the latter may be put in at some future date. The large unit is of the cross-compound triple-cylinder, multiple-expansion parallel-flow type, 60-cycle, three-phase 12,000 volts, 60,000 kilowatts, at eighty-five per cent. power factor.

The coal factor at this plant will likely be one of the lowest had anywhere; in fact, some of those closely associated with the station believe that it will be down near one pound.

The Appalachian Power System

THE South owes much of its development in recent years to cheap power. Fortunately, it abounds in water power, and cheap power is one of the vital natural assets in the industrial growth of a country or section of country. One need but call to mind Lowell, Holyoke, Augusta, Cohoes and Niagara to convince oneself how vital is cheap power.

Of the recent water-power developments in the South, those of the Appalachian Power Company are interesting. This company owns several water-power sites, two of which have been developed. Deserving of special attention is the system of interconnection which it is effecting in Virginia to furnish power for the coal mines, utilities and industrial plants in the southwestern part of Virginia and the eastern part of West Virginia. In addition to the hydro-electric plants which were installed in 1911 and 1912, there has just been completed a modern steam-turbine station of twenty thousand-kilowatt capacity at Glen Lyn.

The interconnection between this company and the Norfolk & Western Railway and the Roanoke Electric Railway and Electric Company greatly facilitated the operating problems of last year, when efforts were being put forth to keep the mines operating at full capacity. The United States Navy derives practically all its coal from this section, which produces the finest steam coal in the country. It was especially valuable during the war for the use of the Navy, because the smoke produced was much less than with any other coal and the visibility of boats using it was therefore much less.

During the period of great industrial activity brought about by the war, there was in this country a serious shortage of power, and this condition will again prevail unless steps are taken to start new developments without delay. The failure of the last Congress to pass the water-power bill and to appropriate the money asked for by Secretary Lane for the purpose of defraying the expenses of a survey of the power situation on the Atlantic Coast is greatly to be deplored, and strong efforts should be made by those interested to educate the next Congress in order to have this legislation passed.

Although the hydro-electric plants of the Appalachian Power Company were built several years ago, the system as a whole represents some unusual features. The units are the most efficient that have ever been tested and reached the high figure of 93.9 per cent. The new steam station is improved in every respect, and high efficiencies are predicted for it. As stated in the article, simplicity was the keynote of the design.

The chief data covering both the hydro-electric and the steam stations, arranged for convenient filing and reference, are given in the article.

Operation at Holtwood

THERE begins in this issue the first of several articles dealing with operation in the large hydro-electric station at Holtwood on the Susquehanna River. The articles treat of the important features of operation, including training of the power-plant crews, governor regulations, governor and general hydraulic maintenance, inspection methods, lubrication of submerged pins in the governor-operating mechanism, maintaining high station efficiency, care of the main transformers, handling ice situation, report and record forms at Holtwood.

These articles should be well received—first, because of the deep, broad interest in water power, so much of which is still undeveloped on this continent, and second, because they deal with operation as practiced in one of the leading stations in this country. There is a third reason why they should be widely read; namely, articles dealing with hydro-electric operation are perhaps among the scarcest things in engineering literature. Search the bibliographies and one will be surprised at the paucity of such engineering literature. It should not be so. Ours is a country that abounds in water power. The war and the woeful shortage of power and coal which it precipitated brought home to the country as nothing else could, the need of turning to commercial use the hundreds of thousands of horsepower of water energy as yet unharnessed. If the developments are to operate most successfully, there must be available to the engineers who operate them and to the young men who later will operate and design them literature which they can use as a tool.

To get it a technical paper must send its editors to the plant. This is and has been the condition. It should not be so. There are volumes of valuable technical data in the files of consulting hydro-electric engineers and others; the chief operators and their assistants, isolated in the mountains as they usually are, could, if they would, make worth-while contributions to their technical literature. The builders of hydro-electric plant equipment, particularly builders of the hydraulic machinery, have shut themselves in too closely for their own and the profession's good. The time is propitious for a widening out of hydro-electric literature. It is hoped the present articles will overcome the inertia and that the opinions and practices of men in this growing field will find wider expression.

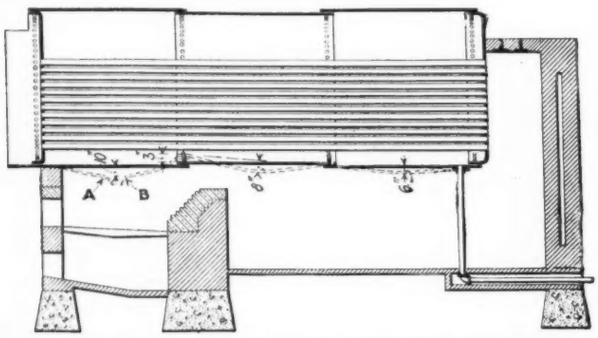
The average steam plant is of the most simple design, and many of the devices found in the larger modern stations are not included in their equipment. The object of the supplement to this issue is to show the application of some of the apparatus and specialties that go to make up a modern steam-power plant. No attempt has been made to incorporate all the apparatus that is to be obtained, but the most essential equipment.

Correspondence

Low Water Ruins Boiler

At about 5 a.m., Jan. 2, a boiler in a plant at the edge of the business district of Salt Lake City, Utah, exploded, but little damage was done to the setting or connections.

The night watchman had been required to get the boilers ready for the fireman. Although the engineer had taken pains to instruct the watchman as to the



DISTORTED PLATES DUE TO OVERHEATING UNDER PRESSURE

duties and had pointed out the necessity of being careful regarding the water, the latter in some way made a serious mistake in assuming that the boiler was full of water, so he opened the blowoff valve, and when the water level appeared to be at two gages, he closed the valve and started a fire in the furnace.

The setting housed two 72-in. return-tubular boilers. The fires had been banked the evening before, and about 60 lb. pressure was on the boiler. Some time after the fires had been started, there was a loud report and fire and steam began blowing from the furnace of one boiler. The engineer was called, but by the time he arrived the pressure had been relieved and all was quiet.

It is evident that the watchman had not ascertained the true level of the water, which was low. He blew out nearly, if not all, that was in the boiler through the blowoff line and the steam from the other boiler, not being prevented by a nonreturn valve, produced an excess pressure on the rapidly heating plates until the bagging drew the plates so thin they could not withstand the pressure, and a rupture followed in the first sheet directly over the fire. The second and third sheets were also badly bagged.

The first sheet appeared to be down about 10 in., the second 8 in. and the third about 6 in., and between the first and second sheets the girth seam was raised about 3 in. The tubes were badly warped and twisted. New plates are to be put on while the boiler remains in place. The dotted line in the illustration gives some idea of the appearance of the bottom of the boiler. The rupture was from *A* to *B*, making a ragged opening 12 in. long and about 1¼ in. at the widest place. The thickness of the plate was less than $\frac{1}{16}$ in. around the hole.

Salt Lake City, Utah. WILLIAM E. PIPER.

Repairing a "Nigger" Cylinder

Following is a description of a repair job to a sawmill "nigger," or log canter. The sawyer had allowed the piston in one of the cylinders to overtravel, resulting in a broken cylinder head and the piston going out far enough to allow the rings to open. When an attempt was made to put the piston back, the rings broke and became wedged between the cylinder and the piston, cracking the cylinder for about two-thirds of its length. There being no spare cylinder, the mill had to shut down.

We sent to the manufacturers for a new cylinder, but could not get delivery for several weeks. The question was how to make repairs. The "nigger" was dismantled and the cylinder sent to be welded, but word came back that the job could not be done. In the meantime the mill foreman had been hunting around town for a substitute cylinder and discovered a section of an old steam-feed cylinder of the right bore, but six feet long, or one foot too long for our purposes, and there was no provision for bolting the valve to the cylinder.

Fig. 1 gives an idea of where the break occurred, and Fig. 2 shows how the new cylinder was shortened and provision made for bolting the control valve to the cylinder. The top did not require a faced surface,

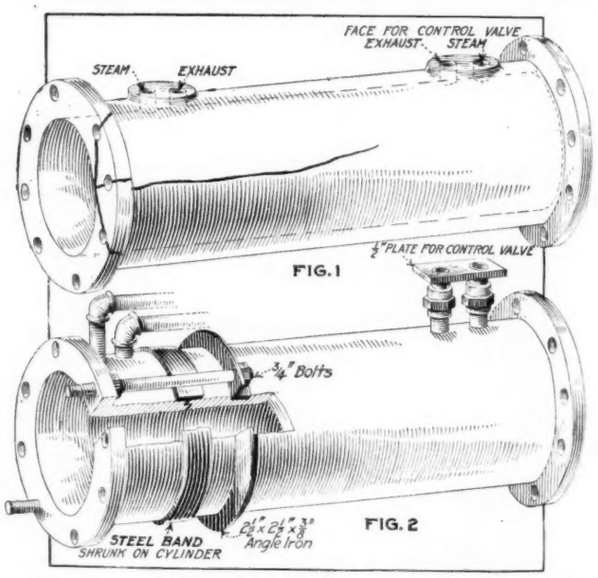


FIG. 1. CRACKED CYLINDER. FIG. 2—HOW NEW CYLINDER WAS SHORTENED AND JOINT REINFORCED

and the piping at the left of Fig. 2 shows how the entering steam and the exhaust were taken care of in the top end of the cylinder, the pipes being coupled to the control valve, which was constructed so as to handle both ends of the cylinder.

This job took 24 hours and the cylinder has been working for several months without giving any trouble.

Vancouver, B. C., Canada. D. J. H. TAYLOR.

Theories of the Mobile Explosion

Careful investigation of the premises, available parts of the boilers and the verbal evidence of others seem to make it practically certain that in the case of the Mobile boiler explosion the initial rupture occurred in the No. 6 Stirling boiler. The evidence is incontrovertible that the lower head of this boiler was very greatly reduced in thickness through corrosion, that there was not sufficient dish for the diameter and pressure, and that the inevitable breathing action had weakened the material at the point of change in curvature from a dish to a flange, so that a crack had developed around a large proportion of the circumference. The shape and characteristics of the blown-out head substantiate this statement.

At the time of our examination, five or six days after the accident took place, the lower drum out of which the head had been blown could not be located, having evidently been cleaned up with other débris and taken away. It is impossible therefore to say where it finally came to rest. It is quite evident, however, from the appearance of the wreckage that the parts of this boiler had been widely separated, and it is probable that the tubes in violently discharging their contents after the sudden release of pressure through the failure of the head, blew the several upper drums upwardly and, of course, tearing away the steam main. Failure of the steam main suddenly released the pressure on the other boilers which were tied into the same line, which would naturally tend to cause explosive action in the interior of each one of such boilers; and it is quite likely, although not susceptible of absolute proof, that this gunlike action of the tubes of No. 5 Stirling boiler violently separated the several drums of that boiler although without rupturing any of them. None of them showed any such deterioration as the failed head of No. 6.

The reduction in pressure due to the failure of the steam main, which probably tore loose the connections to No. 4 Heine boiler, caused an action in the interior of those boilers similar to that described above in connection with the Stirling boilers. In one of the Heine units this action was sufficiently violent to loosen the whole of the tubes, thereby forcing the two water-legs apart. These water-legs, however, being held strongly together at the top edges by means of the shell, bent sharply, and in the case of the rear one the force was sufficient to tear the water-leg in pieces, pulling out the drum head and also starting a rupture which tore the shell considerably at the forward end.

With but minor exceptions of such a nature that no inherent weakness could be attributed thereto, the metal throughout showed excellent characteristics as to ductility.

The tremendous amount of energy freed is shown by the uniform enlargement of many of the stay-bolt and other holes. The consistency of the design of the details is very marked from the way in which failures of the various parts took place. In the case of a riveted joint there was evidence of failure by combined rivet shear, crushing of metal and tearing of net metal between rivets. In the case of throat stays they broke in the shank, both through and outside of the rivet.

None of the lap-riveted joints, with the exception of the one header which was pulled out, failed, the metal in fact tearing through the roundabout joints, leaving both those and the lap-riveted longitudinal joints intact.

The other Heine unit was undamaged so far as internal explosive action is concerned.

From the relative locations alone of the various parts of the several boilers, it is impossible to deduce a conclusion with any certainty as to whether it was the Stirling or the Heine boiler that failed first, but in view of the known weakness of the lower head of the drum of the Stirling boiler and known failures of various types of boilers in recent years from exactly the same phenomena, it is most reasonable and practically beyond peradventure that this is where the initial failure occurred.

The directions in which the drums of the Stirling boilers went are such as would be expected from the failure of the lower drum. The parts of the exploded Heine boiler went in the directions that would be expected from the way in which that boiler exploded, this action being substantially in line with the longitudinal axis of the boiler, there being relatively little side effort. That the force was in this direction was indicated by the position of the unexploded Heine unit, which was more to the front than to the side.

The analogy to the failure of a chain at its weakest link is applicable in this case.

The statement of a negro fireman who claims that he saw the Heine boiler let go first is without weight because it was impossible for him at the point where he was located to see at all clearly any of the boilers, and the Stirling boilers not at all. The interval of time between the two explosions was unquestionably entirely too short to have enabled even a much more intelligent person under such terrifying conditions to have gone through the mental processes necessary to analyze the situation, and any evidence of that sort must unquestionably be regarded as incompetent.

E. R. FISH,
Secretary, Heine Boiler Co.

Phoenixville, Penn.

It is our understanding that you expect to publish an account of the unfortunate boiler explosion which occurred on Feb. 21, 1919, at the Mobile Electric Co., Mobile, Ala.

We inclose herewith sketch[1] which shows the position of the various boilers before and after the explosion. As marked on this sketch boilers Nos. 4-A and 4-B were Heine, and Nos. 5, 6 and 7 Stirling. The head of the mud drum of the Stirling boiler No. 6, which blew out, was thinned down by corrosion, but being a blank head, this thinning down was difficult to detect. This head showed a marked indentation, which can be accounted for only by its having been violently struck by something. A study of the accompanying sketch showing the position of the various boilers before and after the explosion shows conclusively that the Heine boiler No. 4-B exploded first, was catapulted end over end to its final position, and in doing so forced Heine No. 4-A into its final position. The shock forced Stirling No. 5 toward the north and demolished the battery wall between Stirling No. 5 and Stirling No. 6, and in so doing a shock was transmitted to the head of the mud drum of Stirling No. 6, which caused it to fracture. Stirling No. 6 was thrown to its final position, and the combined forces of the explosion of Heine No. 4-B and Stirling No. 6, acting from different directions, the force from Heine No. 4-B being greater than that from Stirling No. 6 caused Stirling

[1]Substantially the same as the map in Fig. 2 on page 433.—Editor.

No. 5 to be carried up and over Stirling No. 6 to the position in which it was found.

Photographs of the parts of Heine No. 4-B and Stirling No. 6 show that the rupture of the Heine boiler was much greater than that of the Stirling, which confirms the conclusion reached in the preceding paragraph. If the initial explosion occurred in Stirling No. 6, it is hardly conceivable that Stirling No. 5 would have been damaged so slightly as has been found to be the case.

No other theory will account for the final position of Stirling No. 5, the drums of which were not ruptured in any way.

The action described above, as having caused the head of Stirling No. 6 to rupture, is precisely the one that took place at the time of the torpedoing of the steamship "Kellog" in July, 1918.

This vessel was fitted with Babcock & Wilcox marine boilers, located three abreast athwartship, thereby presenting the outboard drum head to the side of the ship. The vessel was struck by a torpedo abreast the boilers on the port side, tearing a hole in the ship's side 20 x 40 ft. The 42-in. drum head of the boiler nearest the point struck by the torpedo received the shock which caused it to rupture and blow out. Parts of the ship framing were driven against it as evidenced by many deep indentations. Owing to the original external blow and the resultant internal action, the head was blown to pieces. The head at the other (inboard) end of this drum was badly dented inward, from its impact with the boiler next to it, although the head itself did not rupture. The boiler on which the drum was ruptured was shoved toward the center of the ship, and the two other boilers were moved off their foundations toward the starboard side of the ship, but the drums and pressure parts of these two other boilers were not damaged.

The nature of the explosion was identically the same in both the Mobile Electric Co., and on the "Kellog." At the Mobile Electric Co., Stirling No. 5 was forced toward Stirling No. 6, and the mud drum of Stirling No. 5 or brieks between the mud drum of these two boilers caused a shock to be transmitted to the mud-drum head of Stirling No. 6, indenting it. If the head of Stirling No. 5 had been weaker, that head, rather than that of Stirling No. 6, would undoubtedly have been ruptured; in the shock the weaker head gave way.

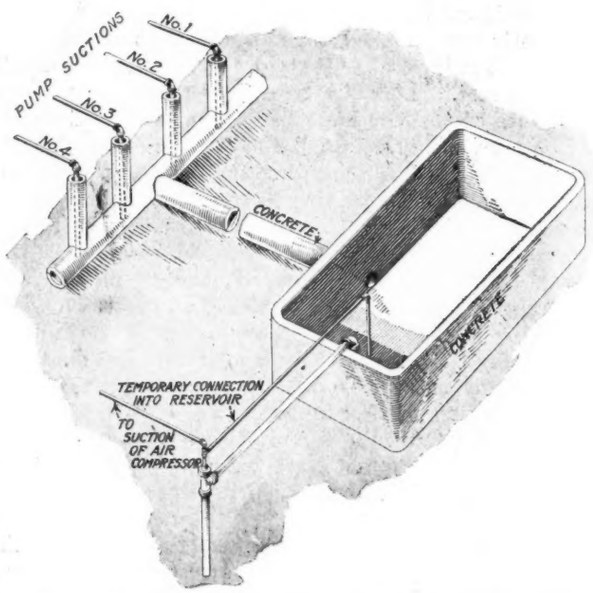
A. G. PRATT,
Second Vice President, Babcock & Wilcox Co.
New York City.

Siphon Emptied Reservoir

During the winter period of overhauling in a California ice plant it became necessary to empty the large concrete reservoir under a cooling tower. No pumping apparatus was available as the boilers were not under pressure during the shutdown period. It was therefore decided by the engineer in charge to make an attempt to siphon the water back into the well from which it had been pumped.

This well was drilled and cased with an 8-in. pipe, inside of which a 2-in. air pipe ran to furnish air for lifting the water. A temporary connection was made from the air line to the bottom of the reservoir, and the original air line was disconnected from the receiver and attached to the suction of a small air compressor. A few turns of the compressor by hand was sufficient to start the siphon working, and the weigh of the 100 ft. column of water going down into the wel instantly pulled the vacuum-gage hand over to the limit. In a few hours the reservoir was empty

The reason for emptying this reservoir was to enable the engineers to dispense with long individual suction lines to several pumps that had been installed at different times. This was accomplished in the following manner: A ditch was dug on a level with the bottom of the reservoir to the center of the pumproom floor, and a 20-in. cement pipe line was laid with suitable tee connections to allow an individual 12-in. well to be brought up to the base of each pumping unit. This allowed each pump suction to become a very simple affair—one nipple, one ell and an 8-ft. length of vertical pipe extending down into each well so that all leaks and deterioration could be taken care of with a minimum of material and



PIPING TO COOLING-TOWER RESERVOIR SHOWING SIMPLE PUMP CONNECTIONS

labor. The resistance due to long and comparatively small lines with several ells was thus eliminated. The water flowed by gravity from the reservoir to the pump wells and stood in each well at a level only slightly lower than that of the reservoir itself. The illustration, although not made to scale, shows the features mentioned.

If this idea is kept in mind while building a new plant and reservoir for possible future pump installations, valuable time and material may be saved when the time arrives for installing additional pumping units.

Pomona, Calif. AMON J. FORTNER.

Our attention has been called to the similarity in principle between the device described by J. M. Purcell in the Feb. 25 issue under the title "Backing Out Broken Setscrew" and a patented device made by the Cleveland Twist Drill Co. under the name of "Ezy-Out Screw Extractor." The essential difference is that Mr. Purcell's device is home-made, from bar stock, whereas the patented device is a finished product made with a taper, although the principle is the same in both cases.—Editor.

Inquiries of General Interest

Evidences of Leaky Condenser Tubes—How does leakage of tubes in a surface condenser become known? L. E.

There will be loss of vacuum from air leakage into the condenser and an excessive delivery of water to the hotwell.

Trouble from Liberation of Air in Suction Pipe—What causes trouble from air in pumping with a suction lift when the suction pipe is tight? W. S. G.

Water under atmospheric conditions contains about 2 per cent. of air in solution, and when the pressure is reduced the air expands. Under a suction lift of 17 ft., if given sufficient time the air would expand to 4 per cent., and with a suction lift of 28 ft. when the pressure would be reduced to an absolute pressure, equivalent to 6 ft. head of water, the air would expand to $34 \div 6 \times 2 = 11.3$ per cent. Ordinarily, the water passes through a suction pipe so quickly that there is not sufficient time for liberation of so much air, but with long suction pipes trouble from liberation of air is more pronounced, because the water is under reduced pressure for a longer time.

Cutting Out Defective Transformer—If three single-phase transformers are connected in delta on the high-tension side and on the low-tension side for diametral connection to a six-phase rotary converter, in case one transformer develops trouble can this unit be cut out and the converter still be operated from the other two transformers? If so what change is it necessary to make in the connections. R. A. C.

The converter may be operated on only two of the transformers. The disabled unit is cut out of circuit on both the high- and low-tension sides, and no changes are made in the connections. This leaves the two transformers in service connected open delta on the high-tension side. The two transformers when connected in open delta, will be able to carry only 58 per cent. of the load of the three transformers when connected closed delta.

Soldering Armature-Coil Leads to Commutator—What is the best method of soldering the coil leads of large armatures to the commutator? What are the objections to using an electric arc or oxyacetylene flame? C. W. R.

The best method of doing the soldering on the commutator of machines of any size is to use a soldering iron. A solder consisting of 50 parts lead and 50 parts tin will have about the correct melting point. The flux best suited for this work is a saturated solution of alcohol and rosin. There are other fluxes that may be used, but many of them will be injurious to the insulation. To do the work to the best advantage, two soldering irons are required, one being heated while the other is in use. The use of an oxyacetylene flame on electric arc for soldering is not practical on account of the temperature being too high and too concentrated. Furthermore, a flame of any kind used for soldering insulated conductors is not to be recommended, because of the difficulty that will be experienced to protect the insulation from burning.

Initial Steam Pressure Too Low for Load—Two boilers have safety valves set to blow at 100 lb., which is not high enough to carry the load on the engine. Another boiler has its safety valve set to blow at 150 lb. How can some steam be taken over from the boiler that is capable of carrying 150 lb. to help out the others? M. F. R.

To raise the pressure of the 100 lb. steam by addition of steam at higher pressure, it would be necessary to perform the mixing intermittently and at periods when there is no communication between the mixing chamber and the source of steam at the lower pressure. The process would need to be similar to admitting steam to a cylinder with cutoff, and subsequently admitting steam of higher initial pressure. Under ordinary plant conditions, the mechanical requirements would be too complex for practical application. The usual method of increasing the effectiveness of steam, by addition of steam at higher pressure, is to perform the mixing by adding the higher-pressure steam throttled down to the lower pressure, as by a pressure-reducing valve, and use the mixture at the lower pressure.

If the engine will not cut off late enough to carry the load when supplied with steam at 100 lb. pressure, the most practical method would be to carry 100 lb. pressure on all boilers; or if that is not feasible, reinforce the 100 lb. steam with steam from the third boiler passed through a reducing valve with a safety valve on the lower-pressure side, large enough to relieve all the steam the higher-pressure boiler is capable of generating at the lower pressure and speed up the engine; or provide large enough cylinder capacity to carry the load with steam supplied at 100 lb. Otherwise it would be necessary to replace the present 100-lb. boilers with boilers capable of supplying steam of higher pressure.

Water-Sealed Stuffing-Box—What is the purpose of a water-sealed stuffing-box, and how is it constructed? W. R.

Water-sealed stuffing-boxes are used for piston rods of pumps employed to obtain a high vacuum, to prevent leakage of air into the pump cylinder. The water sealing consists in keeping the piston rod submerged in water or

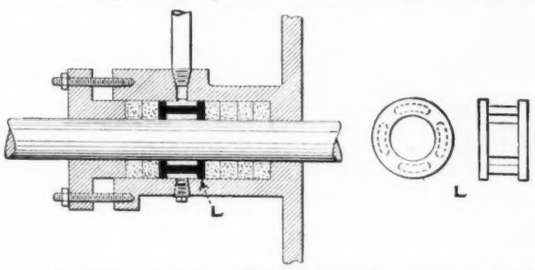


FIG. 1. WATER-SEALED STUFFING-BOX, WITH LANTERN

the atmosphere side of a piston-rod packing. An ordinary stuffing-box, provided it is long enough, can be water-sealed by inserting a lantern *L*, Fig. 1. As shown by the sectional view, the first four rings of the stuffing-box packing are placed in the box, then the lantern, then two more rings.

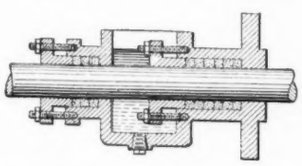


FIG. 2. OPEN WATER BOX

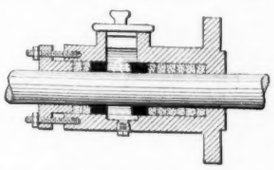


FIG. 3. BOX AND LANTERN

TYPES OF WATER-SEALED STUFFING BOXES

The lantern acts as a separator of the sets of packing rings, and the free space that is left around the rod is connected to the discharge chamber of a water pump or other source of water supply. This prevents air from leaking through the stuffing-box when the latter is only tight enough to prevent leakage of water. Fig. 2 shows the construction of an open water box with two stuffing-boxes, and Fig. 3 shows a modification combining features of Figs. 1 and 2.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for inquiries to receive attention.—EDITOR.]

Turbine Break in Wachusett Hydro-Electric Plant

AN INTERESTING waterwheel failure occurred in the Wachusett station of the Metropolitan Water and Sewerage Board, at Clinton, Mass., on Feb. 17, which was described by William E. Foss, chief engineer of the board, in a paper before the New England Water Works Association Mar. 12. The Wachusett station, a hydro-electric plant of 4000-kw. rating, which is operated in connection with the supply of water to the Greater Boston system, is located just below the Clinton dam. The hydro-electric machinery is on the first floor, and the second and third floors contain offices for the superintendent and the civil-engineering department respectively. The level of the operating-room floor is about 92 ft. below high water in the Wachusett reservoir.

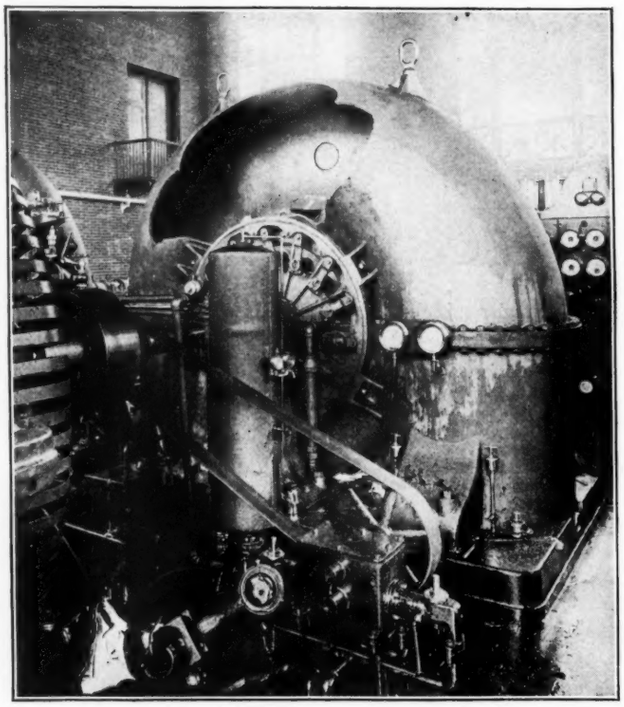


FIG. 1. SHOWING CASING THAT FAILED

The plant includes four 1000-kw. 13,800-volt alternating-current generators direct-connected to horizontal-shaft turbines operating at 400 r.p.m., and two 60-kw. 125-volt direct-current exciters, also operated by hydraulic turbines. Each of the main turbines is provided with a type Q Lombard governor arranged for automatic or hand operation as desired.

The water supply for each unit enters the gate chamber through ports in the upstream face of the dam and, after passing the screens, enters a vertical circular well 7 ft. in diameter through two openings, each 6 ft. high and 2½ ft. wide, which are provided with sluice gates arranged for operation by hand or by electric motor. From the bottom of the circular well the water flows through a horizontal 4-ft. cast-iron pipe for a distance of about 115 ft. to a point under the turbines and rises vertically 15 ft. to the base of the scroll case. In the riser is a hydraulic gate valve which can be operated from the power-station floor. When the plant is in operation, energy is delivered to the New England Power Company's system at 13,800 volts, and energy is also furnished at 2300 volts to the Clinton sewage-pumping station. When the plant is not in operation, the energy required is taken from the New England company.

On Feb. 17 the machinery at the plant was started about 6:30 a.m. as usual and had been running smoothly with exciter No. 2 and units Nos. 1, 2 and 4 in operation for nearly an hour, when the operator noticed that the oil-feed pump of turbine No. 2 was not working properly, and with the helper proceeded to prime the pump with the turbine running. Upon throwing off the pump belt, however, some trouble developed and the operator went to the switchboard and threw the load off the No. 2 unit. As he was returning, the helper pulled out the governor clutch to change from automatic to hand control, and immediately a section of the upper portion of the scroll case having an area of 17.5 sq.ft. blew out.

The escaping water knocked the helper down and swept

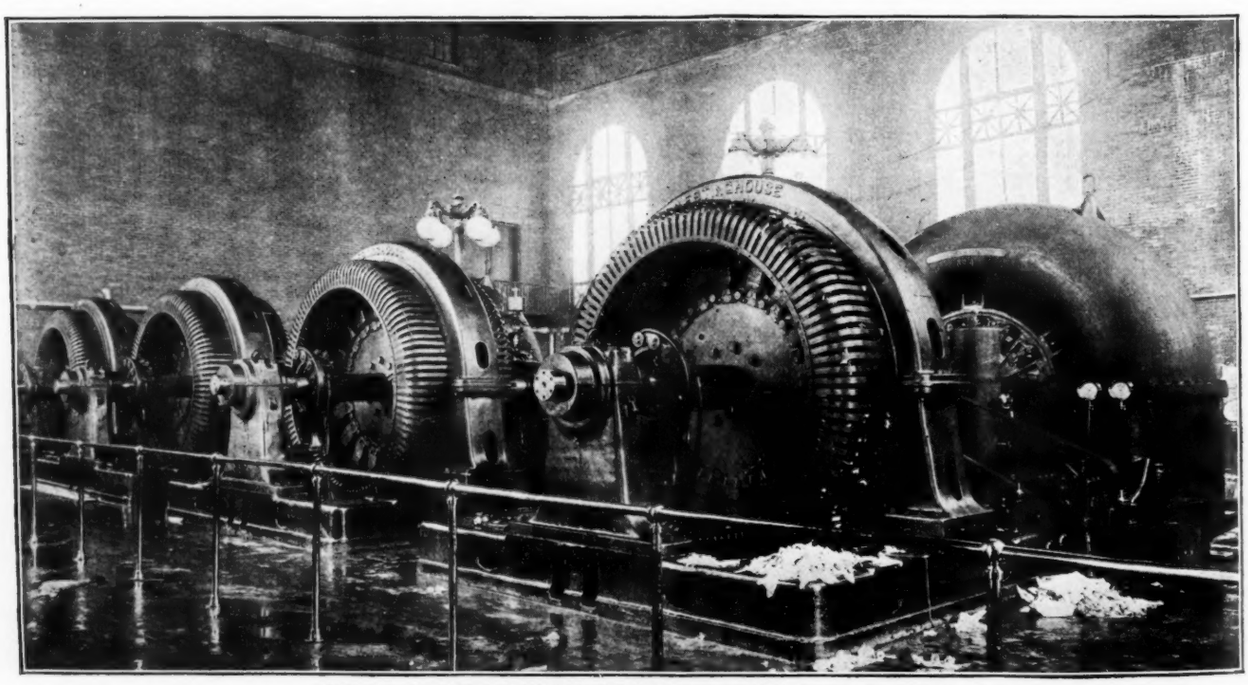


FIG. 2. WATER WHEEL UNITS AT WACHUSETT PLANT

him along the floor between No. 1 and No. 2 generators, by the front door, to a radiator near the westerly end of the station, where he was able to regain his footing, and he left the building through a window. The water was then level with the window sill and about two feet deep over the floor. Meanwhile the operator returned to the switchboard and, after opening all the switches, left the building through the rear door. The two men then went up to the gate chamber and with the assistance of other employees closed the sluice gates and stopped the flow of water about 35 minutes after the break occurred.

The water flowed out of the scroll-case opening under a head of 70 ft., probably in a nearly solid stream, which struck the door leading from the superintendent's office to a small balcony in the power plant, for it is difficult otherwise to account for the effect of the water, which upset a heavy iron safe about 7 ft. high, 4 ft. wide and 2.5 ft. deep and completely wrecked everything else in the office. One of the large windows was broken at a height of about 25 ft. above the floor, and some of the water shot up to the top of the room, broke an interior window, entered the loft and dripped down through the ceiling into the civil-engineering office.

FIG. 3. SHOWING DAMAGE TO OFFICE BY WATER

The water flooded the power station to a depth of about four feet, broke open the front and end doors and flowed out over the lawn, driveway and walks into the river. It also broke down a wooden partition at the air shaft and flowed through the iron grating in the floor into the Wachusett Aqueduct. The heating plant is in a corner of the basement, and there is an opening in the floor above it about 12 ft. long and 6 ft. wide. Water dropped through this opening on the heater and tore off all the magnesia insulation and put out the fire.

The station lighting and power service transformers and many of the instrument transformers were located back of the switchboard near the floor, and the water rose above the top of the cases and displaced the oil, causing short-circuits which grounded all the lines and caused some minor burnouts and insulator breakage on the oil switches. The rotors of generators Nos. 1 and 4 continued to revolve for a time partly submerged in the water, and the insulation of the field and armature coils was cut and scraped in places. The coils on generator No. 2 were also cut and scraped.

As soon as the water had drained out of the building, the heating plant was put into service, and the oil and water were mopped from the floor, walls and apparatus. After running No. 1 exciter generator without load for a time to dry it out by windage, it was put into service to furnish lights, and generators Nos. 1, 3 and 4 were then put in shape and turned over without load during the night to dry them out by windage. On the following day arrangements were made with the Standardizing and Testing Department of the Edison Electric Illuminating Company of Boston for drying out and testing the electrical apparatus. The necessary equipment for this work was shipped from Boston by motor truck late in the afternoon, and the work was started the following morning.

A connection was first made with the New England Power Co.'s line using portable transformer, switching and metering equipment from the Edison laboratory, so that alternating current would be available for drying out and testing the electrical apparatus and for operating the Clinton sewage-pumping station, as the old steam plant there, which had been kept in reserve for emergency use, was not operating satisfactorily. This work was finished on the evening of the second day after the accident and in the meantime canvas had been obtained for covering two of the generators which were being dried out by operating them with armatures short-circuited and a low field excitation; also a motor-driven blower with self-contained heater of electric type was used, and electrically heated ovens were constructed and used for drying out transformers and other apparatus.

Although openings were provided for drainage of electric ducts when these were built into the concrete floor, some of them had become clogged. This made it necessary to disconnect and withdraw the wires in order to dry them out. After the water had been removed from the ducts with swabs, they were dried out by blowing warm air through them. The wires, which had also been dried out, were then replaced and tested.

Pittsburgh Smoke Regulation in 1918

Smoke regulation in Pittsburgh proved of even greater value during the year 1918 than in the preceding four years. The many new conditions presented a much more complicated problem to be worked out in smoke abatement, but progress was made. What the Bureau of Smoke Regulation desires to achieve is to induce people to think what smoke reduction really means. Apart from the fuel saving, reduction of smoke in densely populated areas like Pittsburgh with a low wind velocity, is most important for the preservation of the health and comfort of the inhabitants.

Existing conditions have influenced the owners and operators of plants to advance the following reasons why they should be relieved from the enforcement of the law: 1914, no business; 1915 too much business; 1916, labor scarcity; 1917, war-material production; and 1918 the fuel conditions. That the first four reasons had little standing has been clearly proved, but it required diligence and patience to cope with the fuel situation during 1918. Those plant operators who were so fortunate as to get what coal they needed were required to take any coal they could get. This frequently meant that plants with efficient equipment sufficient to operate their stacks clearly within the ordinance at all times had to contend with great quantities of dirt and refuse in the coal, which precluded the free passage of air through the grates by the formation of slag and clinkers that not only hindered operation but was conducive to smoke and imposed additional burdens on the fireman.

Frequent and justifiable complaints were received during the year about the smoke emitted from public-school buildings. When natural gas was cut off from the schools, serious complications were presented as many of these plants were not competent to burn any other fuel. Therefore, it was necessary to make corrections in plants where the greatest need existed. The Board of Public Education has planned an extensive program that contemplates the revamping of all these plants as soon as possible.

The railroads availed themselves of the lessons taught by their recent strenuous experiences, and even in the face of most exacting fuel conditions adhered to their established plan of supervision and instruction. To appreciate the extent of this undertaking during the past year, it is neces-

sary to contemplate the labor situation, which occasioned the employment of an endless number and variety of firemen, necessitating the teaching of each one the proper method of firing and entailing closer scrutiny on the part of the railroad inspectors.

The number of calls made by inspectors and the time spent inside the plants is indicative of the task devolving upon them, for these, as a rule, were made for the purpose of improving faulty operation in plants where, under normal conditions, the stacks would have been operating without objectionable smoke. The three inspectors made on an average 224 personal visits per month, without taking into consideration the observation of stacks and investigation of complaints. During the year they made 4237 readings or specific observations and 8063 calls.

Complaints received during the year related in a great measure to private residences, and though the regulation of these stacks is not contemplated in the ordinance, each of the 111 complaints received prompt attention. In every instance the nuisance was abated.

As required by Ordinance No. 566, 182 permits were issued to the end of the year 1918, including changes in existing furnaces, new construction and changes in fuel. The fees received for examination of the applications and specifications and covering the issuance of permits amounted to $364. The changes are classified as follows:

CHANGES TOWARD SMOKE ABATEMENT ACCOMPLISHED

No.	Method	Stacks Affected
34	Gas	31
15	Steam jets	13
89	Down-draft boilers	65
191	Smokeless fuel	190
1	Improved stack	1
25	Improved furnaces	22
3	Low-volatile coal	3
6	Smokeless boilers	6
13	Underfeed stokers	10
26	Stokers	17
230	Powdered coal	32
4	Oil	2
1	Down-draft furnace	1
5	Garbage incinerator	5
2	Coke	1
7	Gas and oil	1
2	Coal and powdered coal	1
5	Gas or oil	3
		404

Prosecutions were not made if they could be avoided. Each case had repeated and timely warning and all possible persuasion was brought to bear. These measures failing to get the proper coöperation or evidence of intent to act, suits were entered in twelve cases, all of which had the desired effect, and in every instance the objectionable smoke was abated or such steps taken as to correct the plants permanently.

J. W. Henderson, bureau chief, who had efficiently presided over the affairs of the office for four years and nine months, died on Dec. 19, 1918. W. E. Porter, who had been associated with Mr. Henderson during this time, was appointed to fill the vacancy.

Oil Fuel Versus Coal

Some interesting comparisons between coal and oil as fuels for steam raising were made in a paper read before the Birmingham Association of Mechanical Engineers on Feb. 8. The points in favor of oil in place of coal for warships are: (1) Radius of action increased by 50 per cent. on equal bunker weight, or 80 per cent. on equal bunker space; (2) up to 83 per cent. thermal efficiency instead of 60 per cent.; (3) boilers can be forced up to 50 per cent. above normal rating; (4) control of smoke: entire absence or dense smoke screen as desired; (5) reduction of labor by about 70 per cent.; (6) constructional advantages; (7) bunkering at sea. There are many equally attractive advantages in the application of oil to the mercantile marine. One interesting comparison of coal and oil was made by the American Hawaiian Steamship Co.'s steamship "Arizonan." This vessel took 161 days on the round voyage when burning oil, as compared with 186 days when burning coal, and by economies effected and increased earnings due to saving of bunker spaces and decrease in operating staff, she saved over £4000 on the voyage.

On a comparative test run at Wallsend Slipway with coal and oil on a Scotch marine multitubular type boiler, the following results were obtained, says *The Engineer:*

MEXICAN FUEL OIL

Fuel oil:	
Specific gravity at 60 deg. F.	953
Viscosity at 100 deg. F. (Red. No. 1)	2130 sec.
Flash point (close)	160 deg. F. (above)
Calorific value	18,430
Water evaporated:	
Pounds of water per pound of oil	12.15
Pounds of water per pound of oil (from and at 212 deg. F.)	14.38
Boiler efficiency	73.37 per cent.

COAL

Coal:	
Calorific value in B.t.u.	14,432
Water evaporated:	
Pounds of water per pound of coal	7.76
Pounds of water per pound of coal (from and at 212 deg. F.)	9.31
Boiler efficiency	62.28 per cent.

Efficiencies as high as 84.5 per cent. have been obtained in this country on Scotch marine type boilers, using Mexican fuel oil with the pressure system of oil burning.

At a large London factory which converted its Lancashire boilers from coal to fuel-oil firing, the water evaporation per pound of coal having a calorific value of 11,451 B.t.u. was 7.22 lb., whereas, when working with the pressure system of oil burning, using an oil having a calorific value of 18,750 B.t.u., the evaporation per pound of oil reached 14.44 lb. The quantity of water evaporated per square foot of heating surface on coal was 3.3 lb., whereas oil showed over 7 lb.—thereby increasing the boiler rating by over 100 per cent.

When utilizing oil fuel, the size of a metallurgical furnace is reduced by 30 per cent., and the working area occupied by a furnace and its adjacent machines is only about 50 per cent. of that of the coal-fired furnace, as a stack of coal occupies a certain amount of space in front of the furnace, and the resultant ashes occupy another space behind the furnace. When using oil fuel these spaces may be utilized as furnace pitches, as the oil fuel is carried through pipelines and does not occupy valuable ground space.

Aluminum is usually melted in what is known as a "lift-out" crucible, and the melted metal carried to the molds, whereas brass is melted in "tilting" furnaces. The average oil fuel consumption for lift-out furnaces, when melting low-fusion metals, is about 15 per cent., and for tilting furnaces about 10 per cent. of metal melted; that is, for every 100 lb. of metal melted the lift-out furnace would consume approximately 1½ gal. of oil, and the tilting type approximately 1 gallon.

A series of experimental mixed-fuel tests was carried out at a large London power station on a nutty slack having a calorific value of 10,300 B.t.u., and Mexican fuel oil having a calorific value of 18,750 B.t.u. A boiler efficiency of 74 per cent. was obtained, and the temperature of the combustion chamber was 2850 deg. F. and uptake 628 deg. F. The proportion of oil to coal on a B.t.u. basis was 8 per cent., and on a weight basis 4.96 per cent.

Southern Section A. S. M. E. Holds Meeting

As this issue goes to press a meeting is being held (Mar. 21) by the Southern Section of the American Society of Mechanical Engineers at Atlanta, the Birmingham, Atlanta and New Orleans Sections participating. The program calls for an all-day session beginning with a visit to the Fulton Bag and Cotton Mills in the forenoon, luncheon at the Piedmont Club, an inspection of Camp Jesup and of the Federal prison in the afternoon, dinner at the Druid Hills Golf Club, and an evening session at the Georgia School of Technology, a paper there being presented on "Pulverized Coal as Fuel" by N. C. Harrison. A large attendance is expected.

The Hydro-Electric Power Commission of Ontario has placed an order with the Westinghouse Co. for two 45,000-kv.-a. vertical waterwheel generators of 12,000 volts, three phase, 25 cycles, for their Queenstown Development. These will be the largest waterwheel generators ever constructed and indicate that the Commission thinks there is no time like the present for construction work.

New Publications

MODEL MAKING. By Raymond Francis Yates. Published by Norman W. Henley Publishing Co., New York. Cloth, 390 pages; 6 x 9 in.; 303 illustrations. Price, $3.

Here is a book for the man of mechanical or scientific bent—whether professional or amateur—who has the time and the patience to indulge in the hobby of model construction. The creative instinct is strong in everyone, and this book shows numerous ways in which that impulse may be satisfied. It opens with a description of the workshop and tools of a model engineer, explains numerous operations and processes that must be performed and then goes to the heart of the matter by giving complete instructions for the making of model steam engines, steam turbines, boilers, boiler fittings, boats, submarine with radio control and various other devices. The directions are stated in a clear style and include not only the operations to be carried out but the sizes and the materials of the various parts as well. The text matter is made still more easily understandable by many clear halftones and working drawings of the various models.

COMPRESSED AIR PLANT. By Robert Peele. Published by John Wiley & Sons, Inc., New York. Cloth, 485 pages; 6 x 9 in.; 246 illustrations. Price, $4.25.

This is the third edition of a work that first appeared in 1908, and deals with the production, transmission and use of compressed air, with special reference to mine service. The first half of the book takes up the structure and operation of various kinds of compressors, the theory of air compression, wet and dry compressors, compound compressors, valves and valve motions, performances of compressors, air receivers, speed and pressure regulators, effect of altitude, explosions in compressors and receivers and compression of air by falling water. The other half describes the methods of transmission and use of compressed air, including piping, compressed-air engines, freezing of moisture, reheating air, rock drills, hammer drills, coal-cutting machines, channeling machines, compressed-air mine pumps, and mine haulage by compressed air. This new edition contains a number of chapters that have been entirely rewritten and expanded and features the most recent changes in the design of compressors, particularly the adoption of thin-plate air valves and larger and more efficient intercoolers on stage compressors.

Personals

Chester Mott has been appointed manager of the Denver (Colo.) office of the Sullivan Machinery Co., at 837 Equitable Building.

James E. Barker, consulting engineer, announces the opening of offices at 611-615 Investment Building, Los Angeles, Cal., for the practice of gas, electrical and mechanical engineering.

Capt. H. A. Weaver, recently discharged from the service, will shortly resume his former position as general manager and chief engineer of the Steel City Testing Laboratories at Pittsburgh, Penn.

E. E. Maher, formerly Western manager for the Lea-Courtenay Co., and more recently for the Terry Steam Turbine Co., has opened up offices in the Michigan Boulevard Building, Chicago, handling various lines of mechanical equipment, including the centrifugal pump of the Dayton-Dowd Co., of Quincy, Ill., high-speed steam engines of the Erie Engine Works, etc. Mr. Maher has had long experience in the mechanical field and is particularly well known in the vicinity of Chicago.

Engineering Affairs

The American Chemical Society will hold its spring meeting with the Western New York Section in Buffalo, Apr. 7-11, with headquarters at the Hotel Statler.

Jersey City N. A. S. E. No. 1 held a dinner on Mar. 15 at Fisher's Hall, at which Lieut. Lewis F. Lyne, Jr., a member, who has been Inspector of munitions, Ordnance Department, gave an interesting and instructive talk with blackboard illustrations, on the subject of "Chemical Warfare." Vice National President John J. Calahan also spoke on the welfare of the association. Twenty-two delegates were elected to attend the New Jersey State convention, which will be held at Bayonne, June 7-8.

Miscellaneous News

The Power Plant of the Monongahela Valley Traction Co. at Rivesville, Marion County, W. Va., now under construction, is nearing completion. Power will be furnished by the plant in question for the entire Monongahela Valley. In putting up the Rivesville plant provision has been made for the construction of additional units as they shall become necessary.

West Virginia Hydro-Electric Power—There will hardly be any hydro-electric water-power development during the next two years in West Virginia for two reasons. In the first place the legislature failed to act on a hydro-electric power bill at the regular session of the body, and although the same bill which was pending during the regular session has again been introduced, as a revenue-producing measure, not having been included in the subjects listed for consideration by Governor Cornwell, it is not considered probable that any action will be taken on the measure at the special session. Furthermore, the bond market is such that it is not considered likely that any attempt will be made to float bonds for water-power development, although all the water power in West Virginia is going to waste.

Business Items

Muskegon Boiler Works of Muskegon, Mich., has opened a district sales office in Chicago, located at 1105 Edison Building, with R. L. Baker as manager.

The United Machine and Manufacturing Co., Canton, Ohio, through an agreement with Charles D. Mosher, has acquired all patents, manufacturing and sales rights covering the Mosher separator.

The Sullivan-Machinery Co. announces the establishment of a branch sales office and warehouse at Edificio Oliver, No. 3, Mexico City. Joseph F. Bennett, who has been for a number of years sales engineer at the company's El Paso office, has been placed in charge of the Mexico branch.

The C. T. Coe Co. has purchased the property of the Hafer Foundry and Machine Co., Chambersburg, Penn., and removed its plant from Newark, N. J., to Chambersburg, where it will continue to manufacture Coe turbine blowers and Coe sectional grates in addition to the Hafer patent soot blowers and Hafer shaking grates; also a full line of boiler specialties.

Trade Catalogs

The Jeffrey Pivoted Bucket Carrier. The Jeffrey Manufacturing Co., Columbus, Ohio. Catalog No. 210. Pages 96, 6 x 9¼ in. Fully illustrated.

Boiler Feed Water Heaters and Purifiers Milwaukee Reliance Boiler Works, Milwaukee, Wis. A 15-page catalog showing different types of boiler feed-water heaters and purifiers.

The Strong Machinery and Supply Co., New York City, has issued a 232-page catalog describing and illustrating its motive power specialties. A 3-page index of the numerous products of this company is appended. Chief engineers will find it a useful reference catalog when purchasing equipment.

The Milwaukee Reliance Boiler Works, Milwaukee, Wis., has recently issued its Bulletin No. 101 on "The Sharp-Bassett Combined Steam and Gas Generator." Pages 23, 8 x 10½ in. The bulletin describes and illustrates the first and only practical combined steam and gas generator in existence and gives useful information on the application and use of producer gas generally.

New Construction

PROPOSED WORK

Mass., Cambridge—Atwood & McManus, Vale St., Chelsea, will install a steam heating plant and electric power in the 2-story, 90 x 240 ft. box factory which it plans to build on Aberdeen Ave. Total estimated cost, $110,000. J. F. Thomas, 50 Bromheed St., Boston, Engr.

N. Y., Albany—M. Spiegel, Strand Theater Bldg., New York City, will install a steam heating plant in the 2-story, 75 x 175 ft. theater which he plans to build on Monroe St. Total estimated cost, $150,000. T. Lamb, 644 8th Ave., New York City, Arch.

N. Y., Brooklyn—The Beth Moses Hospital, Hart St. and Stuyvesant Ave., will install a steam heating plant in the 5-story, 90 x 100 ft. addition to the hospital which it plans to build. Total estimated cost, $350,000. H. J. Nurich, 957 Bway., Brooklyn, Arch.

N. Y., Brooklyn—Courtney Marshall Estate, Pierpont St., will install a steam heating plant in the 1-story, 100 x 100 ft. theater which it plans to build on Saratoga Ave. and Macon St. Total estimated cost, $100,000. De Rosa & Pereira, 110 West 40th St., New York City, Arch.

N. Y., Carthage—The St. James Parish Building Committee will install a steam heating plant in the 40 x 100 ft. high school which it plans to build on Mechanics St., to be known as the St. James Augustina Academy. Estimated cost, $60,000.

N. Y., New York—J. F. Murray, 33 Clifton Terrace, Weehawken, N. J., has awarded the contract for the construction of an 8-story, 50 x 100 ft. warehouse at 548 West 39th St., to Harby, Abrons & Melius, 15 East 40th St. A steam heating plant will be installed in same. Total estimated cost, $150,000.

N. Y., New York—The National Bible Institute, 213 West 35th St., will install a steam heating plant in the 15-story, 100 x 100 ft. cremorne mission building which it plans to build at 214-216 West 35th St. McKenzie, Voorhies & Gmelin, 1123 Bway., Arch.

N. Y., New York—The 181st St. Construction Co., 729 Bway., has awarded the contract for the construction of a 3-story, 150 x 200 ft. theater which it plans to build on Bway. and 181st St., to the Fleishman Construction Co., 39th St. and 7th Ave. A steam heating plant will be installed in same. Total estimated cost, $500,000.

N. Y., Oneida—The Central New York Milk Producers' Association will install a boiler, milk handling machinery etc., in the milk station which it plans to build. Total estimated cost, $12,000. S. T. Bridge, Chn.

N. J., New Brunswick—The Long-Landreth-Schneider Co., 226 Cleveland Ave., plans to build a boiler house and addition to water heater factory. Estimated cost, $10,000. Highland Park Building Co., 238 Cleveland Ave., Arch.

Penn., Philadelphia—E. Wolf, 1517 North 16th St., will install a steam heating system in the 7-story, 75 x 156 ft. store and office building which it plans to build on the Southeast Corner of 16th and Market St. Total estimated cost, $400,000. Hoffman Co., Finance Bldg., Arch.

Md., Baltimore—The Standard Oil Co., Pier 2, Pratt and Commerce St., plans to build a 1-story, 45 x 93 ft. addition to its boiler house on 1st Ave.

D. C., Washington—The Bureau of Yards & Docks, Navy Department, received following bids furnishing condensers, aftercoolers and pumps at various Navy Yards; Specification No. 3797:

(1) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for a 1000 kw. turbo-generator at the Navy Yard, Portsmouth, N. H.

(2) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for an 8000 c.f.m. turbo-compressor, at the Navy Yard, Boston, Mass.

(3) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for a 3000 kw. turbo-alternator at the Navy Yard, Philadelphia, Pa.

(4) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for an 8000 c.f.m. turbo-compressor at the Navy Yard, Philadelphia, Pa.

(5) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for a 3000 kw. turbo-alternator at the Navy Yard, Norfolk, Va.

(6) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for an 8000 c.f.m. turbo-compressor at the Navy Yard, Norfolk, Va.

(7) net price and time for 3 surface condensers, 3 air ejectors, 3 motor driven condensate pumps and 3 motor driven circulating pumps for three, 2000 kw. turbo-alternators, and 1 air ejector for the priming system, for the Naval Operating Base, Hampton Roads, Va.

(8) net price and time for 1 surface condenser, 1 air ejector, 1 turbine driven condenser pump, and 1 motor driven circulating pump for a 2000 kw. turbo-alternator at the Navy Yard, Charleston, S. C.

(9) net price and time for 1 surface condenser, 1 air ejector, and 1 turbine driven condensate pump for a 4000 kw. turbo-alternator at the Navy Yard, Mare Island, Calif.

(10) net price and time for 1 after cooler for an 8000 c.f.m. turbo-compressor at the Navy Yard, Boston, Mass.

(11) net price and time for 1 after cooler for an 8000 c.f.m. turbo-compressor and a 6500 c.f.m. reciprocating compressor at the Navy Yard, Philadelphia, Pa.

(12) net price and time for 1 after cooler for an 8000 c.f.m. turbo-compressor and a 6500 c.f.m. reciprocating compressor at the Navy Yard, Norfolk, Va.

(13) net price and time for 1 after cooler for a 2500 c.f.m. and two, 500 c.f.m. reciprocating compressors at the Naval Station, New Orleans, La.

(14) net price and time for 1 jet condenser with removal pump and 1 air ejector for a 6000 c.w. turbo-alternator at the Naval Proving Ground and power factory, Indian Head, Md.

(15) net price and time for 2 jet condensers with removal pumps and 2 air ejectors for two, 500 kw. turbo-alternators at the Naval Station, New Orleans, La.

(16) net price and time for 1 jet condenser with removal pump and 1 air ejector for a 2500 c.f.m. and two 500 c.f.m. reciprocating compressors at the Naval Station, New Orleans, La.

(17) net price and time for 1 motor driven booster pump for the cooling water for an 8000 c.f.m. turbo-compressor at the Navy Yard, Boston, Mass.

(18) net price and time for 1 motor driven booster pump for the cooling water for an 8000 c.f.m. turbo-compressor at the Navy Yard, Philadelphia, Pa.

(19) net price and time for 1 motor driven booster pump for the cooling water for an 8000 c.f.m. turbo-compressor at the Navy Yard, Norfolk, Va.

(20) net price and time for 2 turbine driven fire-and-flushing pumps at the Naval Operating Base, Hampton Roads, Va.

(21) net price and time for one, 5000 g.p.m. motor driven circulating pump for the circulating system at the Naval Station, New Orleans, La.

(22) net price and time for one, 2500 g.p.m. motor driven circulating pump for the circulating system at the Naval Station, New Orleans, La.

(23) net price and time for 3 turbine driven boiler feed pumps at the Naval Station, New Orleans, La.

(24) net price and time for 2 turbine driven fire pumps at the Naval Station, New Orleans, La., from

Alberger Pump & Condenser Co., 140 Cedar St., New York City, (1) $10,447 (150 days); (2) $14,750 (90 days); (3) $21,004 (120 days); (4) $19,652 (90 days); (5) $21,112 (120 days); (6) $19,754 (90 days); (7) $47,045 (150 days); (8) $20,411 (150 days); (9) $25,230 (180 days); (10) $3662 (90 days); (11) $8847 (90 days); (12) $8916 (90 days); (13) $3573 (120 days); (14) $21,312 (150 days); (15) $13,480 (120 days); (16) $5049 (120 days); (17) $1684 (90 days); (18) $1414 (90) days); (19) $1447 (90 days); (20) $11,325 (150 days); (21) $4019 (120 days); (22) $2512 (120 days); (23) $5296 (120 days); (24) $8025 (120 days).

Westinghouse Electric & Mfg. Co., 805 Hibbs Bldg., Washington, D. C., (1) $10,984 (150 days); (2) $16,867 (90 days); (3) $22,252 (120 days); (4) $18,838 (90 days); (5) $22,358 (120 days); (6) $18,941 (90 days); (7) $57,695 (150 days); (8) $21,585 (150 days); (9) $31,470 (150 days); (14) $25,428 (120 days); (15) $18,677 (120 days); (16) $6341 (120 days).

DeLaval Steam Turbine Co., Trenton, N. J., (14) $15,766 (180 days); (15) $12,180 (180 days); (16) $4530 (160 days); (17) $1105 (150 days); (18) $1116 (140 days); (19) $1155 (150 days); (20) $10,144 (180 days); (21) $2634 (180 days); (22) $5520 (180 days); (23) $3716 (180 days); (24) $7992 (180 days).

Wheeler Condenser & Engineering Co., 528 Woodward Bldg., Washington, D. C., (1) $11,735 (150 days); (2) $15,500 (120 days); (3) $20,515 (130 days); (4) $19,230 (120 days); (5) $20,580 (130 days); (6) $19,290 (120 days); (7) $55,615 (180 days); (8) $20,820 (150 days); (9) $29,040 (160 days); (14) $24,830 (135 days); (15) $20,510 (130 days); (16) $7655 (120 days); (17) $1450 (120 days); (18) $1380 (120 days); (19) $1380 (120 days).

Ross Heater & Mfg. Co., 1407 West Ave., Buffalo, N. Y., (1) $10,835, $11,145, $12,295 (150 days); (2) $16,340, $16,960 and $17,170 (90 days); (3) $18,860, $19,710 and $19,920 (120 days); (4) $17,925, $18,650 and $18,860 (90 days); (5) $18,010, $19,765 and $19,970 (120 days); (6) $18,025, $18,750 and $18,960 (90 days); (7) $47,150, $48,900 and $49,350 (150 days); (8) $19,710, $20,360 and $20,565 (150 days). (This party bid as given, with 3 amounts to each item.)

Buffalo Steam Pump Co., 490 Broadway, Buffalo, N. Y. (these prices for delivery only, not erection), (1) $6962 (150 to 180 days); (7) $40,186 (180 days); (8) $16,715 (180 days); (17) $1073 (120 days); (18) $1009 (120 days); (19) $1009 (120 days); (20) $7074 (150 to 180 days); (21) $3298 (200 days); (22) $1894 (200 days); (23) $3408 (120 to 150 days); (24) $6436 (165 days).

Ga., Savannah—The Reliance Fertilizer Co., 106 Bay, will install a steam heating plant in the fertilizer factory which it plans to build. Total estimated cost, $100,000. Lockwood Greene, Healey Bldg., Atlanta, Engr.

Fla., Fernandina—N. B. Borden, Chn. of City Council will soon receive bids for enlarging the ice plant.

Fla., Jacksonville—The city plans to purchase a turbo-generator of 10,000 kw. and a condenser of 32,000 sq.ft. capacity. Estimated cost, $226,764.

Ohio, Akron—The Hippodrome Arcade Co., 434 Akron Savings & Loan Bldg., will install heating equipment, consisting of 2 boilers, 2 vacuum pumps, air washers, etc.; in the 2-story, 99 x 136 ft. theater and arcade which it plans to build. Total estimated cost, $100,000. C. H. Crane & E. G. Kiehler, 2325 Dime Bank Bldg., Detroit, Mich., Arch.

Ohio, Cleveland—J. L. Free Co., 1004 Prospect Ave., will install a steam heating plant in the garage which it plans to build on East 9th St. and Bolivar Rd. Total estimated cost, $100,000. M. Dunning, 304 South Wabash Ave., Chicago, Ill., Engr.

Mich., Lansing—The Board of State Auditors will install a steam heating plant, consisting of boilers, pumps, etc., in the 6-story office and library building which it plans to build. Total estimated cost, $800,000. E. A. Bowd, 127 Allegan St., West, Arch.

Mich., Wakefield—The Board of Education will install steam heating and mechanical ventilation systems in the 2-story, 65 x 150 ft. school building which it plans to build. Total estimated cost, $100,000. Nystrom & Olsen, Palladio Bldg., Duluth, Minn., Arch.

Mich., Wakefield—The Board of Education will install steam heating and mechanical ventilating systems in the 2-story, 80 x 175 ft. manual training and recreation building which it plans to build. Total estimated cost, $150,000. Nystrom & Olsen, Palladio Bldg., Duluth, Minn., Arch.

Kan., Oswego—The city plans election April 1 to vote on $50,000 bond issue for the construction of a new lighting plant.

Kan., Uniontown—The city plans to install an electric lighting plant.

Mo., St. Louis—The McQuay Norris Manufacturing Co., 2808 Locust St., plans to build a power house, in connection with the factory which it plans to build on Cooper St. and Oak Hill R. R. A. J. Mummert, 2808 Locust St., Engr.

CONTRACTS AWARDED

N. Y., Thiells—L. F. Pilcher, State Arch., Capitol, Albany, has awarded the contract for installing steam and heating plant equipment in the Central Heating plant at Letchworth Village, to the Merrill Co., 98 Granite St., Boston, Mass. Estimated cost, $46,984. Noted Jan. 21.

Ohio, Norwood—The Board of Education has awarded the contract for installing steam heating and ventilating systems in the 2-story, 80 x 139 ft. school on Allison St., to the Stanton Heater Co. Estimated cost, $15,170. Noted Jan. 28.

THE COAL MARKET

BOSTON—Current prices per gross ton f.o.b. New York loading ports:

Anthracite

	Company Coal
Egg	$7.80@7.95
Stove	7.95@8.15
Chestnut	8.05@8.35

Bituminous

	Clearfields	Cambrias and Somersets
F.o.b. mines, net tons	$2.15@2.75	$2.80@3.50
Philadelphia, gross tons	4.20@4.90	5.00@5.55
New York, gross tons	4.50@5.25	5.35@5.95
Alongside Boston (water coal), gross tons	6.10@6.85	6.90@7.80

Pocahontas and New River are quoted at $4.70 @5.25 f.o.b. Norfolk and Newport News, Va., for spot coal, and $7.20@8.60 alongside Boston, these prices being on a gross ton basis.

NEW YORK—Current quotations, White Ash, per gross tons, f.o.b. Tidewater, at the lower ports* are as follows:

	Mine	Company Circular		Mine	Company Circular
Broken	$5.95	$7.80	Pea	4.80	6.55
Egg	5.85	7.70	Buckwheat	3.40	5.15
Stove	6.10	7.95	Rice	2.90	4.65
Chestnut	6.20	8.05	Barley	2.40	4.15

Bituminous

	Spot	Contract
South Forks	$2.90 @ $3.50	$3.10 @ $3.50
Cambria County (good grades)	2.80 @ 3.00	2.95 @ 3.00
Clearfield County	2.65 @ 2.95	.....
Reynoldsville	2.65 @ 2.95	2.85 @ 3.00
Quemahoning	2.85 @ 3.10	2.95 @ 3.10
Somerset County (best grades)	2.80 @ 2.95	2.95 @ 3.10
Somerset County (poorer grades)	2.50 @ 2.75	2.75 @ 2.95
Western Maryland	2.50 @ 2.75	2.65 @ 2.85
Fairmont	2.10 @ 2.35	2.35 @ 2.50
Latrobe	2.25 @ 2.40	.....
Greensburg	2.35 @ 2.40	.....
Westmoreland	2.60 @ 2.75	2.65 @ 2.75
Westmoreland run-of-mine	2.40 @ 2.65	2.40 @ 2.65

Quotations at the upper ports for both bituminous and anthracite are 5c. higher on account of the difference in freight rates, and are exclusive of the 3% war freight tax.

PHILADELPHIA—The price per gross ton f.o.b. cars at mines for line shipment and f.o.b. Port Richmond for tide are as follows:

	Line	Tide		Line	Tide
Broken	$5.95	$7.30	Buckwheat	$3.40	$4.45
Egg	5.85	7.20	Rice	2.90	3.80
Stove	6.10	7.45	Boiler	2.70	3.70
Nut	6.20	7.55	Barley	2.40	3.30
Pea	4.80	6.05	Culm	1.25	2.15

CHICAGO—Current prices per ton for Illinois and Indiana coal are as follows:

Illinois

	Southern Illinois	Northern Illinois
Williamson, Saline and Williamson Counties	F.o.b. Mines	F.o.b. Mines
Prepared sizes	$2.75	$3.25
Mine-run	2.35@$2.50	3.00
Screenings	2.05	2.75

BIRMINGHAM—Current prices per net ton f.o.b. mines are as follows:

	Mine-Run	Prepared	Slack and Screenings
Big seam	$2.45	$2.75	$2.40
Black Creek and Cahaba	3.45	3.75	3.05
Jagger - Pratt Corona	2.85	3.05	2.45
Blacksmith	....	5.25	.....

Domestic quoations, slightly increased, are as follows:

	Lump and Nut
Black Creek and Cahaba	3.85@$4.50
Corona	3.40
Jagger	3.50
Montvallo	5.00

ST. LOUIS—The prevailing circular per net ton f.o.b. mines is as follows:

Franklin County	Mt. Olive and Staunton	Standard
Prepared sizes, lump, egg, Nos. 1 and 2 nut	$2.75	.....
Williamson County		
Prepared sizes, lump, egg, nut	$2.55	$2.55	$1.90@2.25
Mine-run	2.20	2.20	1.60@1.70
Screenings	2.05	2.05	.95@1.10
3-in. lump	....	2.30	.....
2-in. lump	....	....	1.75@1.90

Williamson-Franklin rate to St. Louis is $1.10 other rates 92½c.